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PHOTOGRAPHIC SCIENCE AND ENGINEERING
Volume 4, Number 2, March-April 1960

Speed Rating of Reversible Color Films

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As part of the activity of a subcommittee of the American Standards Association, the Ansco Standards Department has conducted some psychophysical tests designed to evaluate the subjective assessment of the speed of color reversal films. The data obtained have resulted in a simple sensitometric method of rating film speeds which is essentially based on the exposure represented by the midpoint of a straight line connecting net densities of 0.20 and 2.00 on the characteristic curve.

Color photography has grown in popularity with the advent of a wide variety of reversible color films. The avid interest of amateurs, advanced amateurs, and professional photographers in high-quality color pictures makes necessary a recognized standard method of indicating the correct exposure for these materials. Such a speed rating method must be universally acceptable to the camera, film, and meter manufacturers, as well as the photographic public.

History

For the past several years, the film manufacturers have been individually providing Exposure Index ratings for color film, for use with tables and computers such as the American Standard Photographic Exposure Computer, PH2.7–1955, and photoelectric exposure meters. Exposure Indexes for these tables and meters have been established by the manufacturers on the basis of practical camera exposures depicting representative scenes. Once such a reference has been established for a given product, various sensitometric methods have been employed to control the speed level in manufacture.

While these methods of measuring the sensitivity of photographic materials have been satisfactory for use by the individual manufacturers to provide the Exposure Index most suitable to their own materials, the need for a common standard is becoming more critical. Lack of standardization already has led to some misrepresentations and exposure failures.

The industry, the photographic press, users and their representative organizations, and photographic scientists have been aware of the need for a uniform sensitometric speed determination standard that would not depend on the repetition of expensive and sometimes misleading practical tests. Such a sensitometric method must be reproducible and must be fully correlated with and representative of average picture exposures. The successful application of a sensitometric criterion for speed rating of color film depends on its usefulness in relation to the average camera and exposure meter, its processing characteristics, and other normal conditions or equipment for which the film has been designed.[1]

A report prepared by the Color Committee of the Society of Motion Picture and Television Engineers in March, 1950, reviews the principles of color sensitometry, describes the fundamental concepts involved and their approximate realization in practical use, and indicates areas in which further research is necessary.[2]

In 1954, the American Standards Association, Photographic Standards Board, formed Subcommittee PH2.12, and assigned to it the task of preparing a standard speed rating for reversible color materials. Initially, the sensitometric methods then being employed by Eastman Kodak Company and by Ansco, the two largest color film manufacturers in the United States, were reviewed and compared. After two years of work, the Subcommittee felt that both methods apparently led to acceptable ratings, but that there were deficiencies in each. To correct these inadequacies, and to arrive at a uniformly acceptable standard of measurement, an interchange of pictorial and sensitometric tests was conducted by Ansco and Eastman Kodak scientific personnel.

Pictorial Correlation

The American Standard Photographic Exposure Computer[3,4] takes into account latitude, month, hour of the day, and scene description (subject type and sky condition) in arriving at an Exposure Index. When the *latitude* zone, light index, and scene index, representing the above, are correlated with the Film Exposure Index, by proper use of tables and/or computer, the correct shutter time and lens opening can be derived.

Photoelectric exposure meters[5] are designed to

Presented at the National Conference, Chicago, 27 October 1959. Received 4 September 1959.

1. L. A. Jones and H. R. Condit, *J. Opt. Soc. Am.*, **38**:123 (1948); *ibid.*, **39**:94 (1949).
2. *Principles of Color Sensitometry, Jour. SMPTE*, **54**:653 (1950).
3. H. G. Morse, *Magazine of Standards*, **26**:173 (1955).
4. *American Standard Photographic Exposure Computer*, ASA PH2.7-1955.
5. *General Purpose Photographic Exposure Meters, Photoelectric Type*, ASA PH2.12-1957.

Fig. 1. Short scale scene with brightness range of approximately 5:1.

Fig. 2. Normal scale scene with brightness range of approximately 20:1.

Fig. 3. Long scale scene with brightness range of approximately 160:1.

combine the light readings, film type, and Exposure Index in a suitable table to provide the shutter and lens aperture settings necessary for proper exposure.

The manufacturers have broad experience in assigning usable average Exposure Index values to color films on an empirical basis. Such experience includes specific, carefully controlled tests; hundreds of in-plant photographs taken by company photographers for technical, publicity, and product promotion programs; and the actual experience of film users. In addition, tests of competitors' products have led to some further adjustments of speed levels in an effort to improve the consistency of the ratings.

Therefore, to establish the basis for the relationship between the above factors in writing a Standard for Film Exposure Index, the following psychophysical tests were conducted:

Two series of carefully controlled pictorial exposures and related sensitometric exposures were made and processed by Ansco at Binghamton, N.Y., and by the Eastman Kodak Company at Rochester, N.Y., on the same hours and dates. The sun angle between these two cities differed by less than 2° of latitude. All pertinent data regarding the brightness values at various parts of the scenes, along with the brightness ranges, were carefully measured with three types of photoelectric exposure meters in good commercial calibration and recorded for future

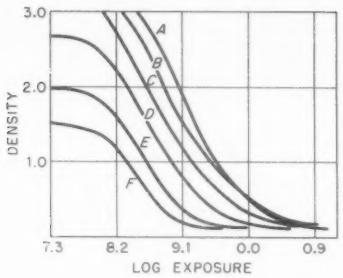

Fig. 4. Sensitometric curves of various products and processing techniques.

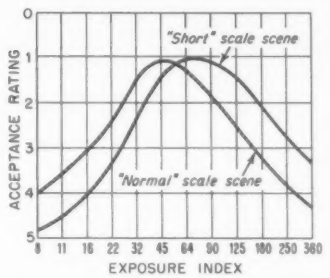

Fig. 5. Acceptance curves comparing two types of pictorial scenes. These are plotted from the averages of the acceptance ratings assigned to each slide by the observers. These curves should not be confused with the distribu'ion curves common in statistical analysis.

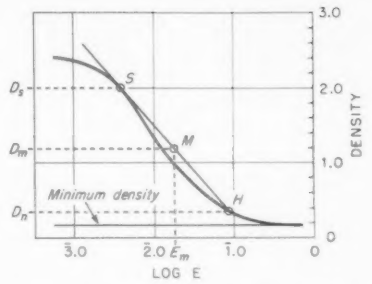

Fig. 6. Proposed sensitometric criteria for ASA Exposure Index for Reversible Color Film.

reference.[6] Three different types of scenes, which could be characterized as "short scale," "normal scale," and "long scale,"[7,8] were exposed. The short scale scenes (see Fig. 1) had a brightness range of about 5:1, the normal scale scenes (see Fig. 2) a range of about 20:1, and the long scale scenes (see Fig. 3) a brightness range of about 160:1.

The pictorial exposures were made at each of twelve diaphragm settings spaced at $\sqrt{2}$ intervals, and so selected as to place the estimated correct exposure near the center of the range.

In the Ansco evaluation, each series of processed pictures of a given scene was randomly presented to a total of 78 observers who assigned "acceptance ratings" to what each considered to be the correctness of the exposure of each slide. Every conceivable effort was made to avoid influencing the decision of the observers. The 2- by 2-in. slides from 35mm camera exposures were projected only, while the $2\frac{1}{4}$- by $2\frac{1}{4}$-in. square slides from roll film came ras were presented both by projection and by transparency illuminator. Then the acceptance ratings were plotted against the practical Exposure Index, based on the American Standard Photographic Exposure Computer, the meter readings, and the manufacturer's in-process standards for each exposure. Thus the slide with the best average score was found. (It appeared on the basis of the accumulated evidence that the ASA Photographic Exposure Computer tended to indicate approximately $\sqrt[3]{2}$ greater exposure than the other references.)

The numerical code for "acceptance ratings" for the correctness of exposure was as follows:

Perfect	0	Marginal	3
Good	1	Poor	4
Acceptable	2	Unusable	5

There are several ways in which psychophysical tests of this kind may be conducted. For example, the Ansco method was to present the slides for projection analysis so that there would be no orderly progression of the exposures. On the other hand, Eastman Kodak found that projecting the slides for viewing in order from the lightest to darkest exposure, and then repeating the series in reverse, produced an "acceptance curve" similar to that of the Ansco method.

A paper by W. Woodbury[9] in this issue supplies more details concerning these methods of evaluating exposure levels for color material. In West Germany recently, S. Rösch,[10,11] has reported the completion of some tests of this type, but he does not describe the details of presentation other than to indicate judgment of the slides "singly on the screen or side-by-side on a light table." He does state, however, that in screening the observers, educational background and personal characteristics and preferences were considered. It was noted, for example, that an artist who preferred to paint in delicate pastels tended to select slightly overexposed transparencies as the best pictures.

At Ansco, in an effort to assure an average group, a broad sampling of impartial observers as well as of trained color workers was used.

In any psychophysical analysis of this sort, the resulting data are based on certain fixed conditions, some of which are more readily apparent than others. Evaluation may be influenced by such things as type of screen, type of projector, viewing angle, and the surround illumination.

Sensitometric curves for the various color products and processing techniques are shown in Fig. 4.

Acceptance curves similar to those shown in Fig. 5 were prepared for different scenes and different color products. As would be expected, reproductions with a short brightness range tended to give a broader

6. P. Moon and D. E. Spencer, *Jour. SMPTE*, **63**:233 (1954).
7. —— and ——, *J. Franklin Inst.*, **258**:113 (1954).
8. —— and ——, *Jour. SMPTE*, **63**:237 (1954).
9. W. Woodbury, *Phot. Sci. & Eng.*, **4**:69 (1960).
10. S. Rösch, *Phot. Korr.*, **95**:67 (1959).
11. *Ibid.*, pp. 7, 28 (1959).

TABLE I
Exposure Index Data from Sensitometric Criterion Compared with the Psychophysical Analysis

Curve	Film	Nominal exposures (processing level)	Average Psycho-physical Exposure Index (pictorial)	Proposed ASA Exposure Index (sensito-metric)
A	E	32	25	21
B	A	16	27	25
C	A	32	44	44
D	A	64	70	90
E	A	125	160	145
F	A	250	232	210

latitude of acceptancy than a long brightness range. To a degree this acceptancy difference was also apparent in comparisons of low-contrast and high-contrast films.

Sensitometric Criterion

Once the acceptance curves had been established, the next step was to correlate the highest average acceptancy, from the point of view of exposure level, with the sensitometric exposure made and processed at the same time.

A variety of methods has been proposed for a sensitometric speed criterion which will lead to an Exposure Index rating for a reversible color film. The most promising of the methods were reviewed critically to find the one showing the most consistent correlation with the practical exposure evidence. One outstanding proposal failed to prove acceptable because of its tendency to overrate the speed of reversible color films having low maximum densities. Another good method appeared to overemphasize heavy densities, resulting in transparencies requiring brighter illumination for proper presentation. Finally a modification of the most outstanding of the sensitometric criteria led to a single method that gave the highest correlation with the pictorial evidence.

In the sensitometric analysis, the characteristic curve of a neutral balanced film is prepared from the American Standard Visual Diffuse Density Readings, Type VI-b (3000K), as defined by the American Standard for Diffuse Transmission Density, PH 2.19–1959 (see Fig. 6). The first step is to locate, on the toe of the curve, point H, which is taken at a density of 0.20 above the minimum density. From point H, a straight line is drawn tangent to the curve at point S. If tangent point S occurs at a density greater than 2.0 above the minimum density, then point S is taken on the curve where the density is 2.0 above the minimum density. On the straight line connecting points H and S, the point M is located where density M, D_m, is equal to D_h plus half the difference of D_s and D_h:

$$D_m = D_h + (D_s - D_h)/2$$

The values of D_h and D_s correspond to the density at point H and point S respectively. The exposure value, E_m (meter-candle-seconds), corresponding to point M, represents the sensitometric criterion from which Exposure Index is computed by the formula:

$$E.I. = 8/E_m$$

This formula for the basic computation of an Exposure Index rating was designed to correlate the sensitometric criterion of neutral balanced film with the pictorial evidence (Table I). In the table, a general agreement may be noted between the sensitometric determination and the psychophysical assignment of Exposure Index.

Application

Obviously, simplicity of the sensitometric criterion, a small risk of bias, reproducibility, and close correlation with practical photography are the main factors governing selection of a method. We feel that the current proposal will fulfill the requirements for an American Standard Method for determining Exposure Index of Reversible Color Film for Still Photography. The method which we have described should provide an Exposure Index for photographic reversible color films that are intended to be viewed either on a transparency illuminator or by projection as slides.

This Exposure Index of reversible color films, when used in conjunction with exposure meters marked with American Standard Exposure Indexes, results in a high percentage of correctly exposed color photographs. The index is based on tests in which the indicated exposure for an average camera and scene would be approximately midway between the least and the greatest exposures required to produce transparencies of excellent quality for viewing at normal luminance levels (about 400 ft-L for transparency illuminators and 40 ft-L for projection screens, open gate).

Conclusion

We would like to point out that the standard Exposure Index method proposed here has resulted from the combined effort of industry, consumer, and scientific organizations. A great deal of time (and money) has been spent in arriving at this threshold of a new American Standard. Time and use should prove the success of this standard Exposure Index method, although most certainly revisions will be required as improved techniques and materials are developed.

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Two Psychophysical Methods for Evaluating the Quality of Projected Color Slides

W. WOODBURY, *Research Laboratories, Eastman Kodak Company, Rochester, N.Y.*

The exposure indexes of reversal color materials for use in miniature cameras are normally based on the results of judgments made of the quality of projected slides which differ only in the exposure given. These slides are presented to the judges in either of two ways — in the order of increasing or decreasing exposure or in a random order with respect to exposure. Although the results with both methods are identical, the advantage appears to be with the ordered-sequence presentation because of the simpler programming and data-handling processes.

In view of the current lack of an officially recognized sensitometric criterion for the determination of exposure indexes for reversal color films, it is the practice of the agencies responsible for such determinations to make exposure-index recommendations on the basis of results obtained with picture tests. Briefly, such tests consist of exposure series of each of several suitable scenes, each scene being illuminated with a light source appropriate for the type of exposure index being determined. Daylight exposure indexes are established with pictures made with daylight, type A indexes are established with pictures made with photoflood lights.

These pictures are subsequently rated for quality by a panel of judges, and these quality ratings are plotted against the exposures which produced the pictures. Figure 1 shows a typical suitable scene from which an exposure-index determination can be made. Figure 2 represents one type of scene which should be avoided because of the nature of the lighting and somewhat unusual brightness values to be found within the scene.

There are, at present, two general procedures that meet the requirement of being reasonably accurate without being unwieldy, or requiring an overwhelming number of observations such as would be necessary with paired comparison judgments of a sufficiently representative number of scene types.

The first method consists in judging an ordered-sequence presentation of a series of transparencies derived from a series of camera exposures varying in uniform increments from overexposure to underexposure (or vice versa), during which the observer assigns a numerical quality value to the slide at the time that the slide is being observed.

The second method differs from the first only in that the slides have been randomized according to a previously arranged program. Here again, the observer assigns a quality value to the slide as it is shown.

In either case, the data are obtained in the form of quality values for each slide, each slide representing a specific exposure. There still remains the task of a sensible reduction of these data to provide a number which, when used with exposure meters calibrated in accordance with the American Standard, will enable the photographer to expose the film properly. The data-reduction methods used for ordered-sequence presentation are identical with those used for random-sequence presentation. Any difference in the final result, therefore, would have to be accounted for in the viewing procedures, and it is with these procedures in mind that a direct comparison has been made between ordered- and random-sequence presentations.

Four outdoor scenes exposed on Kodachrome Film, Daylight Type, were selected as being representative of pictures taken by the casual amateur. In order to eliminate the effect of reciprocity law failure and to provide a time of exposure representative of that used for Kodachrome, Daylight Type, a fixed time of $\frac{1}{25}$ sec was used throughout the series. Exposure was varied by changing the lens aperture.

All slides intended for viewing by projection were viewed by projection. In fact, everything possible was done to simulate an average home viewing situation, with due care being exercised to maintain appropriate details and furnishings in the projection room. In this case a Kodak Cavalcade projector, placed at such a distance from the screen as will provide a screen luminance of 50 ft-L was used, this being considered representative of the screen brightness obtained with modern, high-efficiency amateur projection apparatus. One of the principal objections to paired comparison judging in this situation stems from its lack of compatibility with home viewing, even if it were feasible to judge the hundreds of pairs that would be required.

Presented at the National Conference, Chicago, 27 October 1959. Communication No. 2066 from the Kodak Research Laboratories, received 4 December 1959.

Fig. 1. A typical, front-lighted scene which is suitable for the determination of exposure index.

Fig. 2. A scene unsuited for exposure-index determination because of lighting and scene-luminance conditions.

A series of showings, therefore, was scheduled, which included the following programs:

1. Ordered sequence, light transparencies (overexposed) to dark transparencies (underexposed), and dark-to-light, judged each way.
2. Ordered sequence, light-to-dark, dark-to-light, and light-to-dark again, judged each way for two scenes, plus the ordered sequence, starting with dark-to-light, then light-to-dark, and then dark-to-light again, judged each way for the two remaining scenes. This was done to determine whether the judges would repeat their evaluations the second time through in the same direction.
3. Four different random presentations, one presentation per day for 4 days. Each scene was judged in its entirety before proceeding to the next scene.
4. In association with Program 3, the judges were asked to evaluate the same slides presented in a random array, with the four scenes intermixed. Each day's judging under Programs 3 and 4, therefore, consisted of a random display of each scene followed by a random display of the four scenes intermixed.

The judges were asked to assign numerical quality values to each slide as presented, with the value of 100 representing the judge's opinion of the perfect exposure. These quality values were assigned on the basis of those quality attributes associated with exposure only, ignoring insofar as possible composition of the scene and color aberrations uncorrelated with exposure change. It was not required that the judge assign a value of 100 to any slide of the array if none of the slides appeared

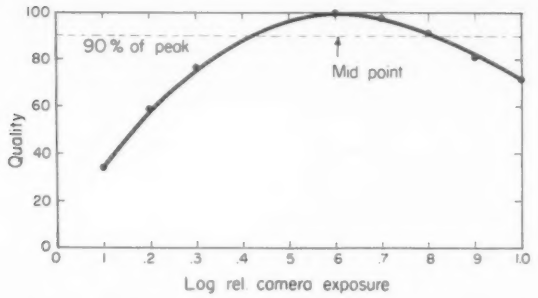

Fig. 3. A typical quality-vs.-exposure-index curve, showing the intersections of the curve with the 90% value line and the midpoint between these intersections from which the exposure-index determination is made.

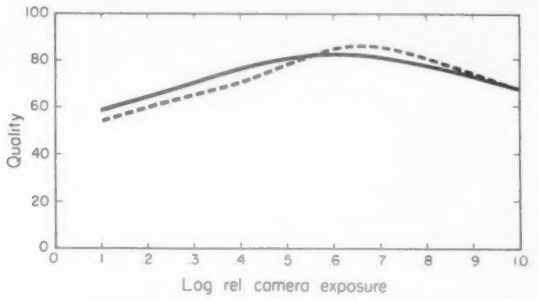

Fig. 4. The solid line represents the quality curve obtained from dark-to-light viewing, whereas the dashed line represents the light-to-dark judgment.

to merit it. As will subsequently be shown, the determination of the best exposure is represented by the approximate location of the peak of the quality-vs.-exposure curve; therefore, the relative values are all that are needed in the final data reduction.

In any comprehensive exposure series such as was obtained for this investigation, there are slides so grossly overexposed or underexposed that there is very little image present. Since it is the general intention to imitate a normal viewing situation, the very poor slides were removed from the series for random presentation in order to eliminate the shock of viewing a very good exposure after an especially poor one, or the other way around.

Each exposure series, therefore, consisted of 10 slides representing a total exposure range of three and one-third stops. With one exception, each judging session was arranged so that a maximum of 80 slides was shown, this number being susbstantially less than that which might influence the results through observer fatigue.

In practice, it is customary to average the quality values assigned by the judges and to plot one curve representing the mean of the curves for the light-to-dark and dark-to-light presentations. A line is drawn at 90% of peak level and the midpoint of the intersections of this line with the quality-vs.-exposure curve is located, from which the exposure index can then be computed with the formula recommended by the American Standards Association, which is, for the case of incident light meters:

$$E.I. = CA^2/IT$$

where C = a constant (in this case $C = 25$)
A = the relative aperature or f-number
I = the illumination incident upon the scene, measured in foot-candles
T = the time of exposure in seconds

A typical quality-vs.-exposure curve is shown in Fig. 3. For the sake of convenience, the abscissas have been labeled in logarithmic units. The midpoint has been selected rather than the peak of the curve, in order to provide equal amounts of latitude in the overexposed and underexposed directions, although the midpoint and the peak of the curve generally coincide. Any separation that may exist seldom amounts to more than one-sixth of a stop.

The quality values assigned by the judges to the slides during the ordered-sequence presentation were averaged and plotted against exposure, one curve for each direction of presentation. It is evident upon examination of the plotted data (e.g., Fig. 4) that the judges have a different opinion of the merits of each slide when viewed from over-exposure to underexposure than that obtained by viewing in the reverse order.

Obviously, therefore, it would be inadvisable to accept either curve as being correct. It is customary to base the assigned exposure index of a color reversal material on the average of the two curves. The resultant averages for these four scenes are shown in Fig. 5.

Since the judges have clearly indicated that they will assign different quality values to the slides of the array when viewed in one order as opposed to the other order, it is logical that the judges' ability to replicate the original data the second time through should be investigated. Two of the scenes were arbitrarily selected to be shown first from dark-to-light, second from light-to-dark, and third from dark-to-light again. The results of this test, as shown in Fig. 6, indicate good repetition of judgment when presentation is in the same order.

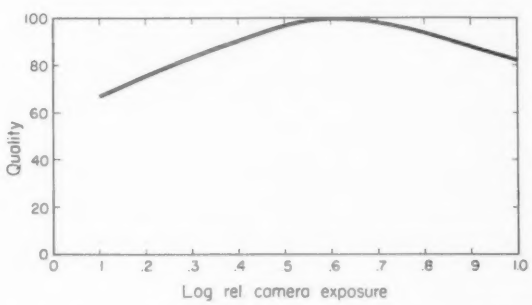

Fig. 5. The average of the curves shown in Fig. 4, and normalized.

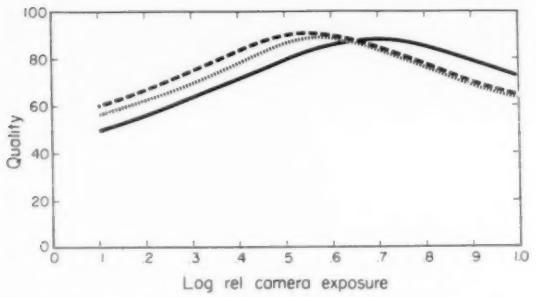

Fig. 6. The dotted and dashed lines represent the results of judgment in one direction. The solid line resulted in judgment in the opposite direction.

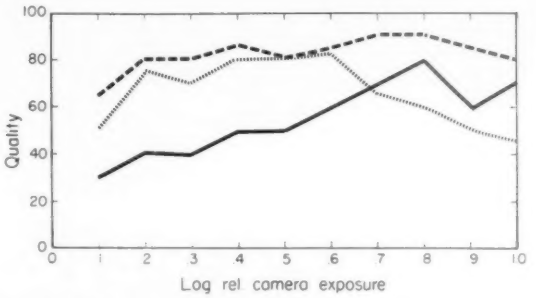

Fig. 7. Results from three individual judgments of the same scene presented in random order.

The ordered-sequence presentation procedure is simple and can be easily repeated by any number of testing agencies provided only the most basic requirements, such as screen luminance, are met. Invariably the resultant curve passes smoothly through the points representing the experimental data. Since the order of presentation is fixed, there is nothing to be gained by conducting more than one light-to-dark and dark-to-light viewing of the series, and, therefore, the entire test is essentially a single operation.

It is obvious from this test that, in an ordered-sequence presentation, the slides must be judged both from light-to-dark and dark-to-light, with the results averaged, in order to overcome the bias that exists in each direction. A judgment series in one direction following a preview in the other direction will not remove this bias.

A separate examination was made of the plotted data obtained from each of several judges, averages of sets from two, three, and four judges, and the average from nine judges. It is evident from an examination of the data thus gathered that the minimum number of judges required to provide a reasonably accurate evaluation of the slides presented will vary with the nature of the scene. A conventional front-lighted scene can be handled competently by as few as five judges, whereas a more unusual scene may require as many as ten. Ten judges have been adequate for any scene yet presented.

It is recognized that a sequential presentation of stimuli may provoke systematic errors in the response of the observers. This has been demonstrated in the quality-vs.-exposure curves obtained in the previously described, ordered-sequence presentation when the slides are viewed in only one order. A truly random presentation of these stimuli should de-systematize the errors brought about by an array which is not completely random. It was found, however, that the quality values assigned to the slides in a random presentation by the judges do not progress systematically with camera exposure.

As in the case of the ordered-sequence presentation, the quality values assigned by the judges after viewing the slides in random order were plotted against exposure. It is evident from a glance at the resultant graph that the judges have some difficulty in assigning quality values to the slides. Figure 7 shows three representative individual judgments of the same scene. Figure 8 shows a smooth curve drawn through the points representing the average data obtained from nine judges at four sessions of the same scene presented in random order with respect to exposure. The scattered points represent the actual values obtained, while the points through which the curve is drawn were derived by means of a mathematical smoothing procedure, which, in most cases, with random-order presentation, was found helpful. The resultant curves, of course, are handled in exactly the same way as the ordered-sequence curves for the determination of exposure index. Once plotted, the curves obtained by averaging the judgments in the two orders of sequence and averaging the judgments in the random order of presentation show a remarkable similarity which tends to establish the validity of either method.

Some attempt has been made to determine the cause for the spread of points found in the random-sequence presentation. Analysis of variance tests applied to the data indicates that this spread is chiefly caused by a random uncertainty of judgment which is considerably greater than any systematic influence of the previously viewed slide, or difference among judges, or differences among a judge's opinions on successive judgment sessions.

Examination of the spread of points from observer to observer and for the same observer from presentation to presentation reveals that the observer is unable to retain in his mind a constant reference scale of quality values from which he can assign quality numbers to the slide being judged and that any such assignment can be considered only an approximation. It is natural that the uncertainty of values varies with the value itself. The higher the value, the more consistent the judge becomes. This is fortunate since the principal interest lies in the highest values. The shape of the quality-vs.- exposure curve in the region below 70 to 80 is of academic interest only.

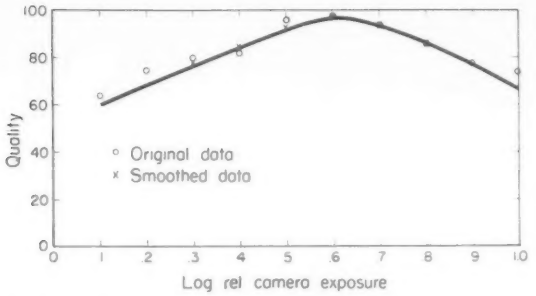

Fig. 8. Final curve obtained by judgment in random-order presentation, showing both the original data and "smoothed" data.

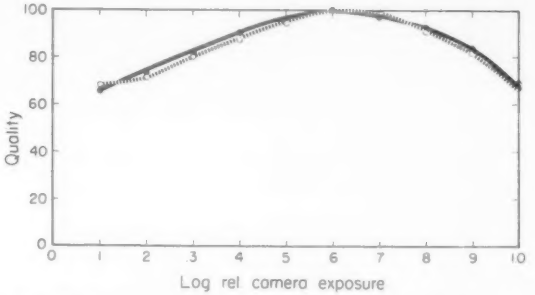

Fig. 9. A direct comparison of the results obtained by the two presentation methods. The solid line represents ordered-sequence, and the dotted line represents random-sequence, presentation.

In addition to the random-presentation procedure just described, the judges evaluated the same slides when presented not only in random order, but with the scenes intermixed. The results of this procedure were essentially the same as those obtained previously and require no amplification.

It may be stated, in summary, that the results of this test indicate that an exposure-index value derived from averaged judgments of the quality of a series of color transparencies presented in exposure sequence judged from light-to-dark and dark-to-light will be essentially the same as that obtained by judging these transparencies randomly presented. In Fig. 9 are compared the results of the two methods as obtained on a typical scene.

Therefore, the choice of presentation is largely a matter of the economics of procedure and ease of data handling. The programming of an ordered sequence is straightforward, whereas a random sequence necessitates use of a table of random numbers. While this is in itself not difficult, it does constitute an extra operation.

On the basis of the criterion of simplicity, therefore, the advantage appears to be with the ordered-sequence presentation, even though each series has to be judged from dark-to-light and light-to-dark. However, a more important consideration is the relative certainty of results obtained from an ordered-sequence presentation. The resultant data are more consistent than those obtained by random-sequence presentation procedures and, consequently, lead to greater accuracy in interpretation.

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A Glass Screen Halftone Sensitometer

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Exposure of halftone dot patterns on film test samples is required in the evaluation of "lith"-type films and processing systems used in the graphic arts industry. Though a process camera equipped with a cross-line glass screen can be used for making halftone exposures which are representative of practical application, this type of equipment is cumbersome and inconvenient for experimental and test use. Discussed here is a simple, compact optical system which will effectively simulate any set of optical conditions obtainable in a process camera. A prototype halftone sensitometer using this system is described.

In the graphic arts industry, ultra-high contrast films of the "lith" type are used in a process camera for the photographic halftone reproduction of a continuous-tone original (which may be a photograph, a painting, or a transparency). Such a process camera produces, by means of a special optical system, patterns of dense, sharply defined halftone dots on the high-contrast emulsion. The processed halftone film is used in the subsequent preparation of photomechanical printing plates for lithography, letterpress, or other processes.

An ideal photographic halftone image for most purposes would exhibit uniform, extremely high density within the dots, while the spaces between dots would have zero density, i.e., the gradient at the dot boundaries would be infinite. The degree to which this ideal is approximated in practice depends upon:

(1) Film emulsion formulation
(2) Developer formulation
(3) Processing factors — e.g., development time, temperature, and agitation
(4) Optical parameters in the halftone exposing system

Developers normally used with "lith"-type films are specifically formulated to produce strong adjacency effects which enhance the boundary gradients in halftone dots. Because of this, the use of conventional macro-image sensitometry is of relatively little value in predicting the halftone performance of a "lith"-type emulsion. The study and evaluation of experimental emulsions, developers, or processing systems requires the exposure of actual halftone dot patterns on film test samples. The processed films may then be evaluated for halftone dot quality by visual microscopy, microdensitometry, or other methods.

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One widely used procedure[1] for exposing halftone test samples employs a process camera equipped with a cross-line glass screen, in exact duplication of graphic arts trade practice. The resulting exposures are certainly representative of practical application and, with proper control, are very reproducible. A process camera, however, can be cumbersome and inconvenient for experimental work, particularly when large numbers of test samples are required.

In the discussion which follows, the optical system of a process camera is compared with a fundamentally equivalent system which is much simpler and more compact.

Glass Screen Halftone Exposing Systems in the Process Camera

The optical conditions of halftone photography in a process camera differ from those of continuous-tone photography because of the introduction of an additional optical component, the halftone screen, between the lens and image plane. An equal-ruled glass cross-line screen (the present discussion is limited to this type of halftone screen) is positioned in a plane near that of the emulsion and parallel to it, at a screen separation distance, s. This arrangement is shown in Fig. 1A.

The proper determination of the distance s between screen rulings and emulsion plane is extremely important since small departures from the optimum value of this screen separation distance will profoundly affect the appearance of the halftone dot pattern. Three different criteria exist for selection of "optimum" screen separation distance:

(1) Calculation based on geometric optics according to the penumbral, or shadow-casting, theory of Clerc[2]

1. F. J. Drago, *Proceedings of the Technical Association of the Graphic Arts 1956*, Chicago, pp. 167–182.
2. L. P. Clerc, *Ilford Manual of Process Work*, Ilford, London, 1946, pp. 161–170.

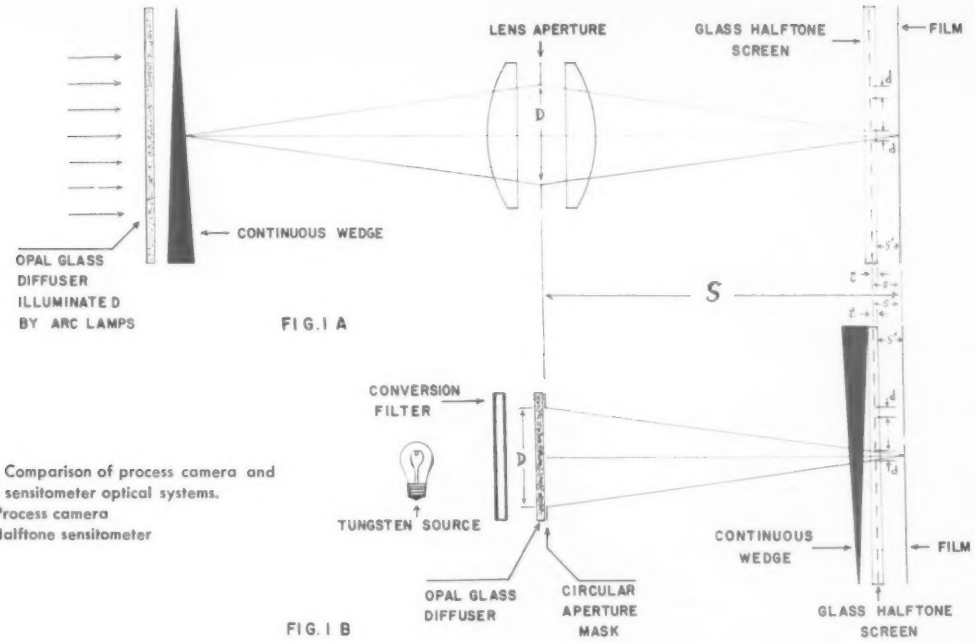

Fig. 1. Comparison of process camera and halftone sensitometer optical systems.
1 A — Process camera
1 B — Halftone sensitometer

(2) Calculation based on the theory that the halftone image is produce by Fresnel diffraction at the edges of the screen "windows," as set forth by Fruwirth and Mertle,[3] by Yule,[4] and by Harrison[5]

(3) Empirical determination by trial, based on the assumption that diffraction and shadow-casting are both significant factors and that their separate quantitative contributions to the halftone image would be difficult or impossible to calculate in a practical exposing system. (According to this hypothesis, the contribution of diffraction is greatest when an extremely fine screen is used, while the simple shadow-casting mechanism predicted by geometric optics tends to predominate in a system where an extremely coarse screen is used.) This view is held by Hellmig and Rebner[6] who published extensive, empirically determined data on screen separation distance as a function of screen ruling and lens aperture.

A more complete discussion of the theory of halftone image formation will be found in the excellent summary provided by Cartwright[7] who reviews the major developments in this field since 1895.

It is important to note that the generalized halftone sensitometer optical system discussed below is capable of simulating *any* given set of process camera optical conditions regardless of the criterion which was used in selecting the process camera screen distance.

Fundamental Requirements in a Halftone Sensitometer

The design of a halftone sensitometer optical system is based on the following considerations:

(1) In a halftone sensitometer the function of a process camera lens can be simulated by a uniformly illuminated circular aperture of equivalent diameter, and in the same plane, as the lens diaphragm. (An exposing system employing a uniformly illuminated aperture and a glass screen for the purpose of making contact screens has been described by Dorst.[8])

(2) For the purpose of generating halftone patterns, any set of optical conditions in a process camera or a halftone sensitometer can be completely characterized by the three parameters: s, R, and S/D, provided S is large compared to s. These parameters are defined as follows:

s = screen separation distance in inches
R = number of screen rulings per inch
S = distance from plane of film emulsion to

3. J. S. Mertle, *Process Photography and Plate Making*, Cramer Dry Plate Company, St. Louis, 1948, pp. 34–44.
4. J. A. C. Yule, *J. Franklin Inst.*, **235:** 483 (1943).
5. V. G. W. Harrison, *J. Phot. Sci.*, Section B of *Phot. J.*, **92:** 74 (1952).
6. E. Hellmig and W. Rebner, *Agfa Repro-Mitteilungen*, 4 (1956): Heft 8, 34-p. pamphlet, "Agfa-Rasterschlüssel."
7. H. M. Cartwright, *J. Phot. Sci.*, **7:** 1 (1959).
8. P. W. Dorst, *A Method of Designing and Making Contact Screens*, Lithographic Technical Foundation Research Bulletin No. 16, New York, 1951.

plane of lens diaphragm or equivalent illuminated aperture
and D = effective diameter of lens diaphragm or measured diameter of equivalent illuminated aperture. (Because of the magnifying effect of the rear lens element, we must actually equate the *measured* diameter of the plain illuminated aperture with the *effective* diameter of the lens diaphragm aperture, which is equal to F/f, where F = focal length and f = relative aperture as normally calibrated on the lens barrel.)

If a halftone sensitometer is so constructed that the values of s, R, and S/D are identical with those in a given set of process camera conditions, the two systems will be optically equivalent and will produce identical halftone patterns.

The equivalence of two such systems is illustrated in Fig. 1. In the process camera system in Fig. 1A, a test film is exposed by halftone photography of a transparent neutral density continuous wedge which is diffusely illuminated by white flame carbon arc. The modulation of exposure intensity by means of a continuous wedge produces on the film test sample a continuous, graduated pattern of halftone dot sizes.

Figure 1B shows a halftone sensitometer system where the camera lens has been replaced by an equivalent circular aperture, diffusely illuminated by a filtered tungsten source. In the two systems, s, R, and S/D are identical. While the process camera system of Fig. 1A images the continuous wedge sharply in the emulsion plane by means of the lens, the halftone sensitometer system of Fig. 1B has no imaging lens and, therefore, exposure intensity is modulated by positioning the wedge between the illuminated aperture and the screen, in a plane close to that of the screen. (In this arrangement, a type of wedge which has extremely low light-scattering properties must be used. Photographic film wedges, for example, are unsatisfactory.) In a camera system it is evident that the distance, S, between lens diaphragm and emulsion plane is constrained by imaging requirements which play no part in generating the halftone patterns. In a halftone sensitometer system, obviously, there are no such restrictions and, so long as the ratio S/D is held constant, S can be decreased substantially in order to obtain a more compact design than is indicated by Fig. 1B. However, S should not be made so small that the angle subtended, at the center of the illuminated aperture, by the diagonal of the image area on the halftone test sample exceeds the 46° angular coverage of a typical process lens. Thus, where L is the diameter of the image field at the film plane, the lower limit for S in a halftone sensitometer is given by:

$$S \geqslant L/2 \tan 23°$$

It should be noted that the screen separation distance, s, is the optical path distance between the plane of the screen *rulings* and the emulsion plane. For convenience in practical measurement, the air space, s', between emulsion plane and rear cover glass of screen is required:

$$s' = s - t/n \qquad (1)$$

where t is the thickness, in inches, of the rear cover glass and n is its index of refraction. For American and European screens we may assume without significant error that $n = 1.5$. Equation (1) may then be written:

$$s' = s - \tfrac{2}{3}t \qquad (2)$$

In the design of a halftone sensitometer to duplicate a given set of process camera conditions, the value of s in both systems must always be identical

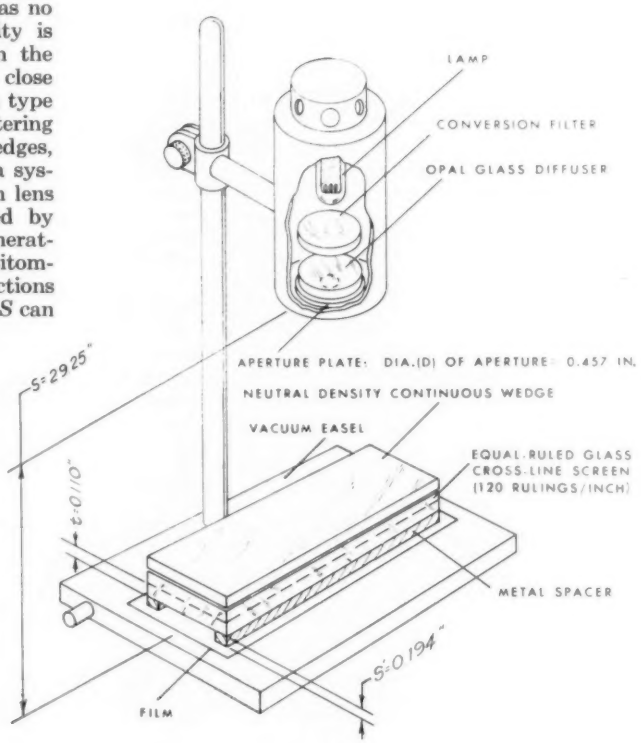

Fig. 2. Prototype halftone sensitometer.

while the value of s' may not be the same because of differences in screen cover glass thickness.

Design of a Prototype Halftone Sensitometer

Process Camera Optical Conditions to Be Simulated

The prototype halftone sensitometer shown schematically in Fig. 2 simulates the optical conditions in a process camera operated at 1:1 magnification, at lens aperture $f/32$, using a 120-lines/in. equal-ruled glass cross-line screen with screen separation distance calculated on the basis of geometric optics in accordance with widespread trade practice in the graphic arts industry. This type of calculation proceeds from the simple geometric relationship:

$$s/d = S/D$$

where, referring to Fig. 1A, s = screen separation distance, d = side of a square "window" in the equal-ruled screen, S = distance between lens diaphragm and emulsion plane, and D = effective diameter of lens diaphragm.

At 1:1 magnification, if f = relative aperture or lens stop,

$$S/D = 2f \tag{3}$$

Where the number of screen rulings is denoted by R,

$$d = 1/2R$$

Hence at 1:1 magnification the screen separation is given by:

$$s = f/R \tag{4}$$

For a 120-lines/in. screen and lens aperture $f/32$, Eq. (4) becomes:

$$s = {}^{32}/_{120} = 0.267 \text{ in.}$$

Halftone Sensitometer Parameters

In the prototype halftone sensitometer, the values of the three parameters s, R, and S/D were made identical with those in the camera. A 120-lines/in. screen was used so that $R = 120$. Since the screen used in the halftone sensitometer had a rear cover glass thickness, t, of 0.110 in., the air space required to obtain a screen separation distance of $s = 0.267$ in. was calculated from Eq. (2):

$$s' = 0.267 - (\tfrac{2}{3})\ (0.110) = 0.194 \text{ in.}$$

The value of S/D for the camera conditions at lens aperture $f/32$ was obtained from Eq. (3):

$$S/D = 2 \times 32 = 64$$

The prototype halftone sensitometer utilized an available circular aperture plate where $D = 0.457$ in., and therefore $S = 64D = 29.25$ in.

Mechanical Arrangement of Components

As shown in Fig. 2, the prototype apparatus consists of:

(1) A tungsten lamp, a conversion filter, and an opal glass diffuser positioned in contact with a circular aperture in a metal mask

(2) A screen-and-wedge assembly consisting of: a neutral density continuous wedge (density range 0–2.0) and a 120-lines/in. equal-ruled glass cross-line screen, to which are fastened metal spacers of a thickness equal to the required air space, s'. Unused areas of the screen cover glass are covered with a dull black mask to exclude extraneous light and prevent multiple reflections between cover glass and emulsion.

(3) A vacuum easel to hold the film firmly in a plane parallel to that of the screen

Operation

With the screen-and-wedge assembly removed, the film is placed, emulsion side up, in vacuum contact with the easel. The screen-and-wedge assembly is then placed on the film so that the metal spacers rest on the emulsion surface.

An exposure of appropriate duration (typically, 20 sec) is then made.

Conclusion

The generalized optical configuration which produces halftone dot patterns when an equal-ruled glass cross-line screen is used in a process camera can be simulated by means of a fundamentally equivalent, non-imaging optical system of simple construction. A prototype instrument of the type described in this paper has consistently produced images which show excellent experimental agreement with those produced under the corresponding optical conditions in a process camera.

By extending the basic design illustrated by the prototype apparatus, a more flexible instrument can be devised to simulate a variety of other glass screen halftone techniques used in the graphic arts industry:

(1) A "multiple-stop exposure" (several screened image exposures, superposed on a single film, each made with a different lens aperture or f-stop) can easily be simulated with an iris diaphragm substituted for the fixed aperture shown in Fig. 2.

(2) A supplementary "flash" exposure (a uniform, non-image exposure through the screen) can be made if means are provided for removing the continuous wedge from the optical system without disturbing the screen.

(3) A supplementary non-screen, image exposure can be simulated by providing a means for removing the screen from the system without disturbing the wedge.

Acknowledgment

Acknowledgment is made to A. W. Grumbine for his valuable assistance in the design and construction of the prototype apparatus.

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An Automatic Gamma-Ray Sensitometer Using Cobalt-60 Foil Sources

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A sensitometer is described for exposing film between lead-foil intensifying screens in a four-step sensitometric series, using thin cobalt-60 foils as the radioactive sources. With source activities totaling about 7 millicuries, exposure times for industrial-type x-ray film range from 10 to 200 sec. Film samples in lead-screen cassettes are stacked in a hopper outside the source shielding. From the hopper they are automatically transported to the exposing position in sequence, exposed, and discharged outside the shielding. Shielding is sufficient to reduce the radiation to a factor of two or three above background. The mathematical theory of the design of the sensitometer is also presented.

In the quality-control testing of x-ray emulsions, the Film Testing Division of Eastman Kodak Company utilizes exposures from a variety of x-ray and radioactive sources. One type of test involves obtaining a sensitometric series of exposures to gamma radiation typical of that used in the field of industrial radiography. In such radiography, the film is usually exposed while sandwiched between lead-foil intensifying screens. From the sensitometric exposure series, the characteristic curve of the emulsion sample, and hence speed, contrast, etc., for this type of application, is obtained.

For many years, such an exposure series was made by modulating the radiation from a radium source with lead step tablets.[1] A variety of systems, including time-scale and multi-source intensity-scale exposure methods, as well as step-tablet modulation have been reported by others for similar purposes.[2,3] In general, such methods require either exposure times of several hours using sources of low enough activity for safe and easy manipulation, or extensive shielding and safety precautions with sources of sufficient activity to yield adequate exposure in a short time. Space requirements and radiation-scatter problems frequently make shielding with absorbing materials impractical. Distance may be substituted for shielding but it then becomes necessary to conduct the exposures in locations inconveniently remote from personnel-occupied or film-storage areas.

Presented at the National Conference, Chicago, 27 October 1959. Communication No. 2047 from the Kodak Research Laboratories, received 2 October 1959.

1. V. G. McInich and S. W. Foor, unpublished data, Film Testing Division, Kodak Park Works, Eastman Kodak Co., 1947.
2. D. P. Jones, *Phot. Eng.*, **6**: 167 (1955).
3. W. C. Brandsma, R. J. Panos, and T. T. Reboul, *Phot. Sci. & Eng.*, **1**: 9 (1957).

With the large increase in recent years of industrial radiography using high-energy x- and gamma-rays, the development of a more convenient testing facility which would not involve long delays for exposure became necessary. The principal specifications for this development were: (1) exposure times not to exceed 1 hr for the slowest emulsions to be tested; (2) operation sufficiently automatic that an operator is not required in constant attendance; (3) radiation shielding sufficient to permit location of the device relatively near film-storage areas in the same laboratory as other equipment involved in testing these types of film. This last specification led to the choice of 0.7 milliroentgen per hour as a design objective for the maximum radiation leakage outside the shielding. With regard to personnel safety, this leakage figure limits maximum possible radiation dosage to at least a factor of 10 below applicable limits recommended by the National Committee on Radiation Protection.

Sensitometer Design Principles

If the requirement of a short exposure time were to be satisfied by simply increasing the source strength, the sensitometer would require some 40 curies of cobalt-60 and tons of shielding. Such a method of providing a sensitometric exposure series is an exceedingly inefficient means of utilizing the radiation flux emitted by a source since less than 0.1% of the flux reaches the required exposure area of the film. The remaining 99.9+% must be absorbed in massive shielding without contributing to the exposure.

If exposures can be made with the film in intimate contact with the radioactive source, then nearly

half of the available radiation flux reaches the film.* Consequently, a much smaller source can be used and the shielding problems are considerably simplified.

A number of systems for producing a sensitometric exposure series or continuous "wedge" exposure by placing the film very near a distributed source were analyzed mathematically. Both linear and planar sources were considered with various relative film and/or source motions. Several of these systems may have been workable but most of them involved complex mechanical systems for producing the relative source-film motion.

The least complicated design, finally selected, uses a separate planar source for each step of an intensity-scale exposure series. The film to be exposed is sandwiched between lead-foil intensifying screens and rapidly brought into as close contact as practical with the sources. The film is held in this position for the duration of the exposure and then rapidly retracted to terminate the exposure.†

The sources must be spaced so that radiation from one source does not appreciably affect the exposure of film areas over adjacent sources. Thus, only a limited number of steps of an exposure series can be obtained on a reasonable-size film sample. Additional steps, however, can be obtained by exposing additional samples for other times. This procedure is valid since, unlike light exposure, there is no reciprocity failure or intermittency effect with x- or gamma-rays at all exposure levels below that required for reversal.[4,5] Thus, either an intensity-scale or time-scale exposure series, or a mixture of the two, can be used without materially affecting the results.

Also, at least for practical radiographic purposes, the sensitometric-curve shape, except for placement along the log exposure axis (speed), is independent of the x- or gamma-ray source used for exposure. Therefore, curve shape can be obtained from an x-ray exposure (a more readily modulated source of ionizing radiation), and the exposure to the gamma-ray sources can be used to establish speed, thus completely defining the sensitometric curve of the film for the gamma-ray source in question. The validity of this procedure has been verified by Newton et al.[6] and is in agreement with work done by Tochilin et al.[7] and more recently by Splettstosser and Seemann.[8]

*For all practical purposes, the radiation flux from an element of area of a flat cobalt-60 source is independent of the angle of emission since the self-absorption for gamma radiation may be neglected. The sensitivity of the film also remains essentially constant with respect to angle of incidence since its absorption is small for gamma radiation. It should be noted that, unlike light, x-radiation or gamma radiation is so penetrating that grains are exposed throughout the volume of the emulsion. Hence, the cosine law does not hold either for the gamma-ray emitter or for the film as a receiver.

† A somewhat similar sensitometer is described by Brandsma et al.[3] These instruments were developed independently but are basically identical in method of exposure.

4. M. Ehrlich and W. L. McLaughlin, *J. Opt. Soc. Amer.*, **46:** 797 (1956).

5. M. Ehrlich, *ibid.*, 801.

6. J. A. Newton, W. R. Rust, and E. W. Junker, unpublished data, Film Testing Division, Kodak Park Works, Eastman Kodak Co., 1957.

Design Considerations

In order to determine the source diameter, activity, spacing from the film and from adjacent sources, etc., the radiation field equation near a plane-circular source was derived mathematically (see Appendix I). This equation has been derived previously by others.[9] It is assumed that the source is of zero thickness. Since a practical source can only approximate this condition, the equation for a source in the form of a right circular cylinder was also derived. The general case for the radiation field near such a source cannot readily be expressed in closed form. However, the special case of the intensity along the axis of the cylinder was derived and evaluated (see Appendix II). For thin sources such as those used in the final sensitometer, the assumption that the source could be considered as a plane was found to be valid within a few percent for the intensities along the axis of the cylinder.

Figure 1 illustrates the calculated distribution of intensity, normalized for a source of radius (a), at the film plane as a function of distance (b) from the axis of the source. The four curves are for different source-to-film distances (h). The curves are normalized so that they are applicable to various source radii, source-to-film distances, displacements from the axis, and source activities ($q\Gamma$).

Most x-ray films exposed in this sensitometer are coated with an emulsion on each side of the film support. Assuming a source-to-film distance of 0.015 in., the emulsion adjacent to the source receives approximately 1.2 times as much exposure as the more distant emulsion. This difference in exposure will produce a sensitometric curve shape that is slightly different from that obtained by exposing each emulsion equally, because of the nonlinear relationship between exposure and density. This results in an error of only about 1% in determining the gamma-ray speed of the radiographic films.

The following specifications were used with the derived equations to determine required source dimensions and placement:

1. The film-to-source distance should be 0.015 in. to allow space for a lead-foil intensifying screen in contact with the film, an abrasion-resistant cover on the lead screen on the side toward the source, and a protective cover over the radioactive material.

2. With a uniformly distributed source, the exposure of the film should be uniform to within ±1% over a 0.25-in. diameter area in the center of the exposed region.

7. E. Tochilin, B. W. Shumway, and G. D. Kohler, *Radiation Res.*, **4:** 467 (1956).

8. H. R. Splettstosser and H. E. Seemann, unpublished data, Research Laboratories, Eastman Kodak Co., 1959.

9. W. V. Mayneord, *Brit. J. Radiol.*, **5:** 675 (1932).

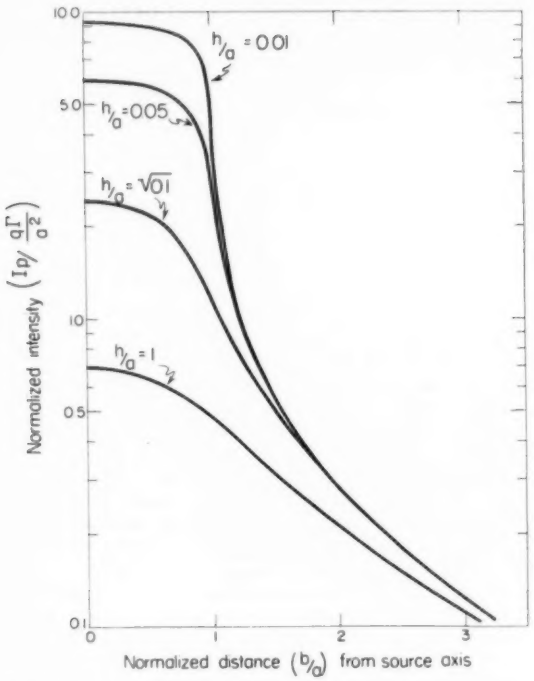

Fig. 1. Radiation distribution about a thin disk of uniformly emitting radioactive material. The normalized intensity vs. distance from the axis of the source is plotted for four ratios of height-to-source radius (h/a). The radiation field is symmetrical about the axis of the source ($b/a = 0$). (The equation is derived in Appendix I.)

3. Radiation reaching this 0.25-in. diameter area from adjacent sources should contribute less than 1% to the exposure.

4. Adjacent sources should produce exposures differing by a factor of 2.

5. The most active of the four sources should produce sufficient exposure in 10 sec with lead screens, to develop to a density of 3.0 on the most sensitive x-ray films.

To satisfy all these specifications, the sources must be at least 0.72 in. in diameter, the center-to-center spacing of adjacent sources must be at least 1.85 in., and the most active source requires 3.9 millicuries of cobalt-60.

Source Bar and Shielding

Figure 2 shows the final machine utilizing four sources, in a design fully meeting the requirements for short exposure times and safe, automatic operation in an occupied area.

The sources consist of either circular foils or electroplatings of cobalt-60, 0.75 in. in diameter and 0.001 in. or less in thickness, sealed in a stainless-steel bar, as shown in Fig. 3. They are spaced 2 in. apart on centers and in contact with 0.005-in.-thick

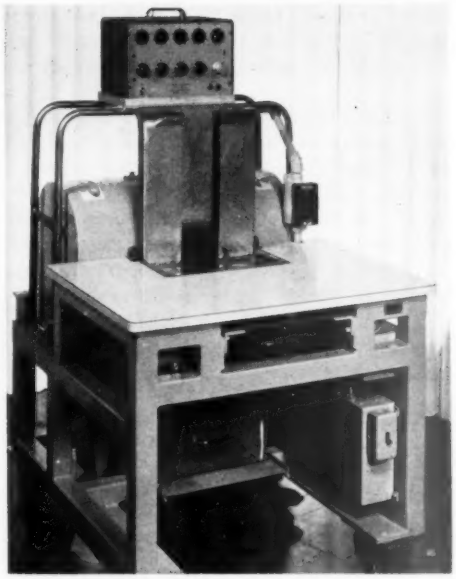

Fig. 2. Cobalt-60 sensitometer.

stainless-steel "windows" in the face of the bar. The total activity of these sources is a little more than 7 millicuries, distributed in the ratios 1:2:4:8, i.e., each source differs from adjacent ones by a factor of 2.

This source bar was made to specification, loaded, and sealed by Technical Operations, Inc., Burlington, Mass. It is mounted on a tungsten alloy (Heavimet) cylinder in a steel-jacketed lead container (Fig. 4), which serves both as shipping container and as part of the shielding of the complete instrument. For shipment, the source bar is rotated away from the container opening, as in Fig. 4, so that the Heavimet cylinder shields the opening.

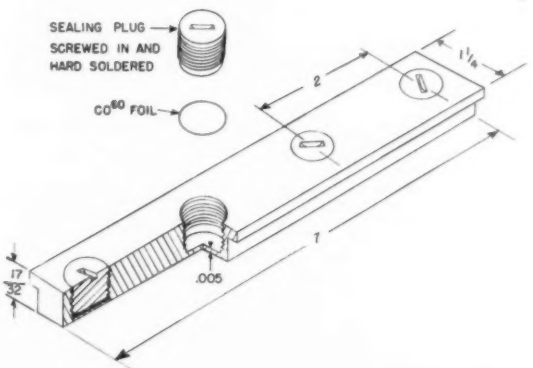

Fig. 3. Cobalt-60 source bar. The bar and plugs are made of stainless steel. The four cobalt-60 sources are either foils, as shown or thin electroplatings.

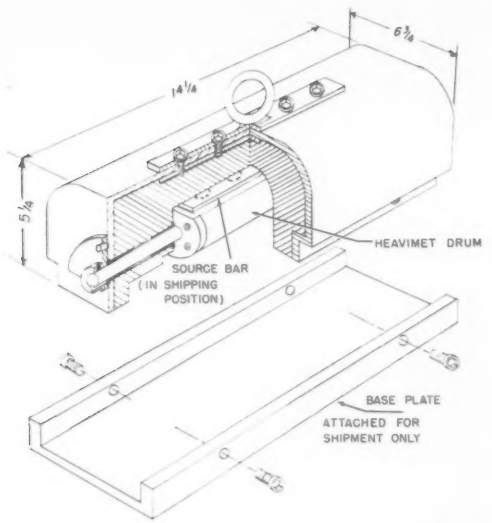

Fig. 4. Source bar in "closed" position in "shipping container." The Heavimet drum with source bar is rotated 180° to "open" position in this container when assembled with the rest of the sensitometer.

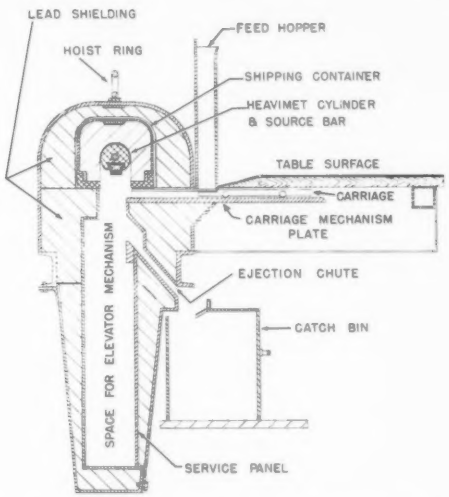

Fig. 5. Vertical section through the sensitometer showing shielding and general arrangement.

A key-operated lock, working against flats on the cylinder shaft, locks the cylinder in position. When this container is assembled with the additional shielding and mechanism, as illustrated in Fig. 5, the cylinder is locked in position with the source bar facing the opening. Projecting pins on flanges at the ends of the cylinder shaft catch under lugs of the support saddle to prevent removal of the shipping container from the assembly without first rotating the source bar into the shielded position.

With the source bar in position for use in the complete assembly (Figs. 2 and 5), the shielding against primary radiation consists of a minimum of $5\frac{1}{2}$ in. of lead or its equivalent in other materials and distance. As indicated by a Geiger-Müller survey meter, and by photographic measurements, this reduces radiation at the outer surfaces of the shielding to not more than 0.3 milliroentgen/hr, which is well below the design maximum of 0.7 milliroentgen/hr. Two narrow open channels are provided through which film samples are automatically fed and ejected during operation. These channels are not in line with the source bar, thus requiring rays from the source to undergo at least one scattering before emerging from the shielding. Measurement of this scattered or secondary radiation indicates an intensity of about 3.0 milliroentgens/hr right at the outer end of the channels. This, however, falls off rapidly with distance so that within 3 in. from the openings in line with the channels it is down to less than 0.7 milliroentgen/hr. These openings can only be reached with the tips of the fingers and, in operating the instrument, even this is seldom necessary. The average radiation intensity (including background) in the region occupied by an operator in close attendance is of the order of 0.03 to 0.05 milliroentgen/hr, which is only 2 or 3 times normal background radiation.

Film Cassettes

For exposure, film samples cut into 12-in. by 35-mm strips are placed in the cassettes shown in Fig. 6. The cassettes consist of a stainless-steel sleeve and a fiberboard-polyethylene fold-over insert containing the lead screens. The sleeves and inserts have an "open window" in one side somewhat larger than the face of the source bar so that when the cassettes are positioned for exposure the source bar projects through the window to bear against the lead-screen and film sandwich. Thus, the 0.015-in. space between the film surface and the surface of the cobalt-60 sources is filled with the front lead screen (0.005 in. thick), a 0.005-in.-thick polyethylene laminate on the lead screen for abrasion protection (side opposite the film), and the 0.005-in.-thick stainless-steel window of the source bar.

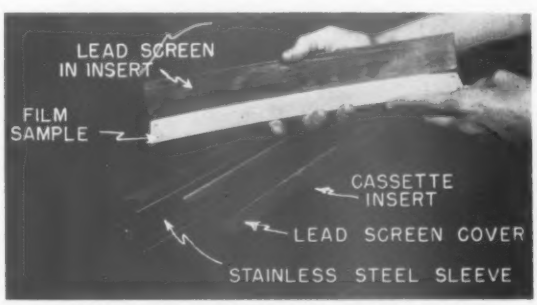

Fig. 6. Film cassettes with lead intensifying screens.

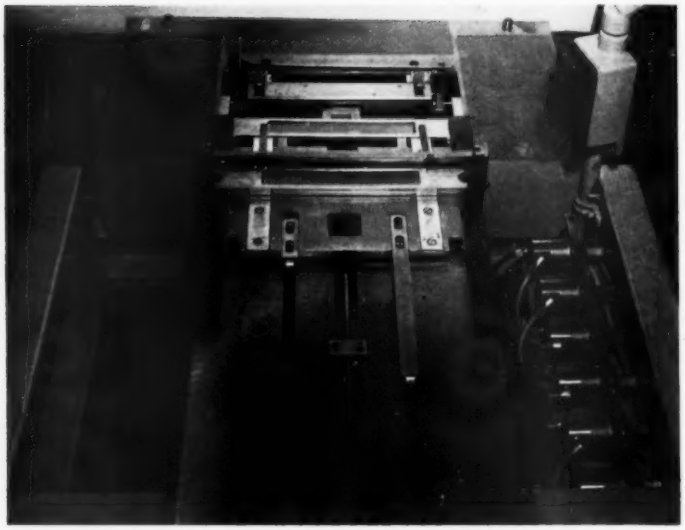

Fig. 7. View of sensitometer with upper shielding, shipping container, feed hopper, and table top removed. Carriage is shown pushing a cassette toward the elevator platform. Two additional cassettes are in the hopper position.

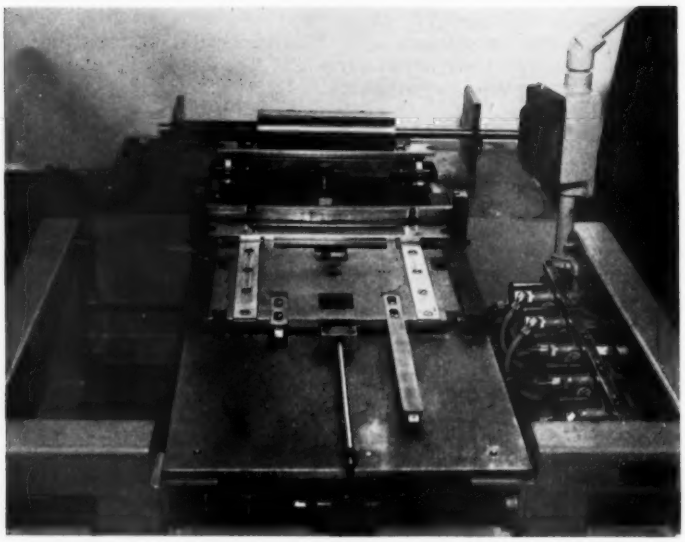

Fig. 8. Cassette in exposing position against a dummy source bar which is mounted in normal position on a temporary alignment jig. The carriage is retracted for picking up the next cassette from hopper position.

Cassette-Transport Mechanism

The cassettes containing film samples are manually loaded, window side up, in the feed hopper (see Fig. 5), in batches of 50 or less. When the sensitometer is started, the bottom cassette is transported by a pneumatically driven carriage through the feed channel in the shielding and positioned on the platform of an elevator mechanism. This elevator is driven to three positions by two pneumatic cylinders in series. From the load (central) position it lifts the cassette about 2 in. to press it against the source bar and closes a switch to start a timer (top of Fig. 2) which has been preset by the operator. At the end of this preset time, both cylinders of the elevator mechanism retract, lowering the cassette to a point below the loading position where a cam pushes it off the elevator platform into the ejection chute through which it discharges to a catch bin outside the shielding. The discharge action also resets the timer and starts a repeat cycle with the next cassette. The machine continues to cycle automatically until the last cassette in the feed hopper has been discharged. If desired, additional cassettes for the same exposure time may be added at any time until the hopper is full. Figures 7, 8, and 9 show the machine with sections of the shielding removed to expose the transport mechanism.

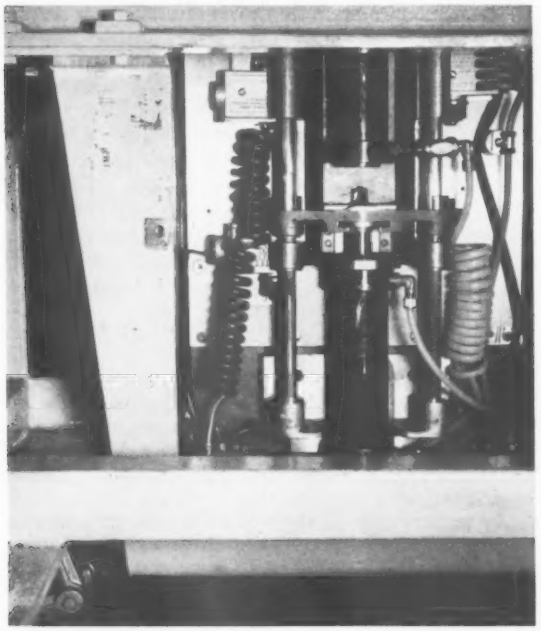

Fig. 9. Pneumatic cylinders, limit switches, and coiled (flexible) air and electrical lines of the elevator mechanism as seen by removing service access panel in the lower shielding.

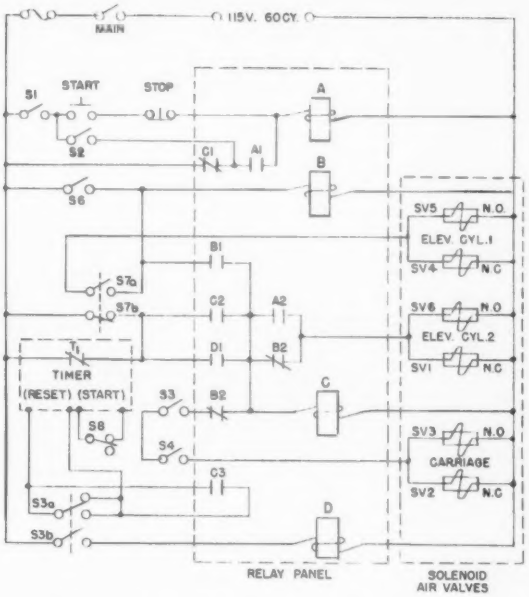

Fig. 10. Schematic diagram of electrical control circuit.

Sequence Control and Electrical Circuit

The compressed-air supply to the three double-acting pneumatic cylinders, which power the mechanical motions for transporting and positioning the film cassettes, is controlled by solenoid valves in the electrical circuit shown in Fig. 10. The control elements in this circuit are the manual start–stop buttons, the preset timer, and limit switches mechanically operated by the pneumatic cylinders near the ends of their strokes. The operation is strictly sequential in that each phase of the cycle is dependent on completion of the preceding one. Table I, in the next column, lists the control switches in sequence of operation, along with their mode of actuation and the function controlled.

With the air-pressure regulator set at 35 psi, the operating time for a complete cycle is about 3.6 sec plus the exposing time.

The exposure timer is a Freed Transformer Co. electronic-counting-type preset timer, utilizing 60-cycle line frequency as the timing base. Five decade selector switches on the timer panel permit setting the timed interval in 0.1-sec increments from 0.1 to 10,000 sec. It is automatically reset at the end of a cycle by the sequential operation of limit switch S3a and relay contact C3 as the cassette elevators reach down (discharge) position.

TABLE I

Switch	Operated by	Function controlled
Main	Operator	Energizes circuit
S1, S2	Cassette in hopper	Enables start circuit
S3a	Both elevator cylinders down	Resets timer
S3b	Both elevator cylinders down	Enables start circuit
S4	Elevator cylinder 2 down	Enables start circuit
Start	Operator	Starts elevator cylinder 1 up
S5	Elevator cylinder 1 up	Starts carriage in (Moves cassette to elevator platform)
S6	Carriage in	Starts carriage out
S7a, S7b	Carriage out	Starts elevator 2 up (Moves cassette to expose position)
S8	Elevator cylinder 2 up	Starts timer
T	Timer at preset time	Starts elevators down (Discharges cassette)
S3a, S3b, S4	Both elevator cylinders down	Starts cycle repeat
Stop	Operator (optional)	Prevents cycle repeat

Notes: Timer is reset by a momentary "open" in reset circuit.
Timer operates when start circuit is open.

Radiation Protection During Maintenance

The complete carriage mechanism is mounted on an easily removed plate which projects into the feed

channel. Removal of this plate provides an opening large enough for the insertion of a 1.25-in.-thick Heavimet slab to block off radiation from the elevator-mechanism space. This permits removal of the service panel in the lower shielding for access to the elevator mechanism without chance of exposure to abnormal radiation levels. The complete elevator mechanism is also mounted on a single plate which may be removed through the opening provided by removal of the service panel.

It is anticipated that the cobalt-60 sources will be renewed when they have decayed to about half their initial activity (after 5 years). To avoid a long "down time" for the sensitometer while new sources are being installed, a second shipping-container assembly was built which can be loaded in advance with the new source bar. The exchange can then be made with a down time of as little as 1 hr. The old source bar, in its shipping container, may then be returned to the supplier for disposal and reloading as required.

Source Calibration

A photographic photometry method was used to calibrate the effective exposures produced at the exposure plane in the sensitometer. A conventional radiographic cobalt-60 capsule, certified as to gamma-ray intensity by the National Bureau of Standards, was used as the reference source. The photographic medium used was a specially selected and seasoned coating of Kodak Industrial X-ray Film, Type AA.

Under carefully controlled conditions, samples of the film were exposed to the reference source, to the sources in the cobalt-60 sensitometer, and to 80-kv x-rays in a 20-step time-scale sensitometer. All samples were processed together in a sensitometric processing machine, using conventional x-ray solutions. The x-ray exposures were used to determine precisely the shape of the x-ray sensitometric curve of the film and the reference-source exposures were used to establish the gamma-ray log E scale for this curve. Values from this scale corresponding to the densities of the cobalt-60 sensitometer exposures were then taken as the log E values for the instrument for the particular exposure time involved.

The exposures to the reference source were made in the laboratories of Technical Operations, Inc., Burlington, Mass., whereas the other exposures were made, and the processing was done, in Rochester, N.Y. This necessitated an appreciable time lapse between the reference exposures and processing. Therefore, a latent-image-keeping exposure series was made during this period and the results were used to correct for the small changes encountered. Also, special vaporproof packaging was used to minimize the effect of variable atmospheric conditions on the keeping properties of the film during transit. Statistical study of the calibration data indicates that the values obtained are accurate within ± 0.03 in log E.

Performance

The four-step exposure series produced by this instrument does not alone give sufficient information for an accurately defined sensitometric curve. However, in conjunction with a more detailed x-ray exposure series for defining curve shape, it does give complete and reliable information for evaluating the gamma-ray sensitometric properties of films. The response of the sample to x-ray exposure is also usually desired at the same time and x-ray sensitometers are available in the same laboratory area for this purpose. Therefore, very little additional work is involved in evaluating the two sets of exposures in a common curve, and this is more than offset by the convenience of location of the exposing facility and the greatly reduced exposure times required. Furthermore, if more detailed data for a curve from cobalt-60 exposure only are desired, they can be obtained simply by exposing two or more sample strips at different exposure times.

As an example of the exposure time required, a density of 3.5 to 4.0 was produced on Kodak Industrial X-ray Film, Type AA, by the most intense source in about 1 min, at the time of calibration of the source bar. Other materials required from 10 sec for the fastest films, to about 20 min for the slowest films normally tested with gamma-ray exposure. Since cobalt-60 decays at a known exponential rate (half-life of 5.26 years), it is necessary to adjust these exposure times frequently to compensate for the loss in intensity. In practice, this adjustment is made once each month, which holds the exposures constant within 0.01 in log roentgens. In about 5 years, the exposure times will have doubled, at which time it is anticipated the source bar will be replaced with a new one.

Some difficulty was encountered in obtaining the desired uniformity over the area of the electroplated sources used in the original source bar. This nonuniformity of source activity causes a mottle pattern within the spot area which requires precise positioning in the densitometer to get reproducible results. With a densitometer having a 5-mm reading aperture, density variation equivalent to about 0.02 in log exposure is obtained within the central 1-cm circular area of the steps. The most intense source, which is a foil rather than an electroplating, shows much better uniformity. Preparation of foil sources of desired strengths is being investigated so that future source bars can be prepared in this way rather than by electroplating.

Acknowledgments

We wish to extend special thanks to Dr. Eric T. Clark, of Technical Operations, Inc., for his cooperation and suggestions in the design and construction of the cobalt-60 source bar. Also, we thank W. B. Hausler and R. J. Herberger, of the Kodak Park Engineering Division, for their contributions to the mechanical and electrical design and to J. A. Newton, F. H. Holland, and E. W. Junker,

of the Kodak Park Film Testing Division for experimental work, checking calculations, and similar operations in the various schemes considered in this development.

APPENDIXES

APPENDIX I — Derivation of the Radiation Field Distribution Around a Thin Flat Disk of Uniformly Emitting Radioactive Material

Assumptions:

1. The source is assumed to have zero thickness.
2. The self-absorption of the source is negligible.

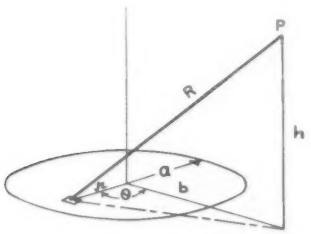

Figure 11

The intensity I_p at a point P, Fig. 11, a distance b from the axis and a distance h from the plane of a uniformly emitting radioactive disk of radius a is proportional to the summation of intensities contributed by the individual elements of area $r\ dr\ d\Theta$ and is inversely proportional to the square of the distance R from these elements of area.

Therefore:

$$\Delta I_p = \frac{q\Gamma}{\text{Area}} \cdot \frac{\Delta\ \text{Area}}{R^2},$$

where q is the activity of the source and Γ is the gamma-ray dose-rate constant relating gamma-ray intensity to source activity. (For Co-60, Γ = C 13.5 cm²-r/mc-hr) Then,

$$I_p = \frac{q\Gamma}{\pi a^2} \int_o^a \int_o^{2\pi} \frac{r\ dr\ d\Theta}{r^2 + h^2 + b^2 - 2br\cos\Theta}$$

Integrating between these limits yields:

$$I_p = \frac{q\Gamma}{a^2} \ln \frac{a^2 - b^2 + h^2 + \sqrt{(a^2 - b^2 + h^2)^2 + 4b^2h^2}}{2h^2}$$

For the special case of point P lying on the axis of the disk ($b = 0$), the general solution reduces to:

$$I_p = \frac{q\Gamma}{a^2} \ln \frac{a^2 + h^2}{h^2}$$

APPENDIX II — Derivation of the Radiation Field Along the Axis of a Right Circular Cylinder of Uniformly Emitting Radioactive Material

The intensity I_p at a point P, Fig. 12, on the axis and a distance h from the end of a uniformly emitting right circular cylinder of radioactive material of radius a and

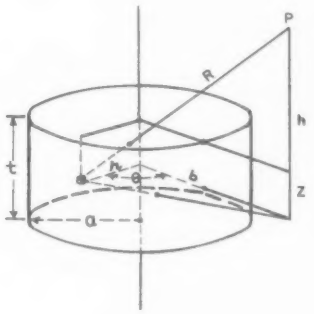

Figure 12

height t is proportional to the summation of intensities contributed by the individual elements of volume $r\ dr\ d\Theta\ dz$ and is inversely proportional to the square of the distance R from the element of volume. The self-absorption of the source is assumed to be negligible.

Therefore:

$$\Delta I_p = \frac{q\Gamma}{\text{Volume}} \cdot \frac{\Delta\ \text{Volume}}{R^2},$$

where q is the activity of the source and Γ is the gamma-ray dose-rate constant.

Then,

$$I_p = \frac{q\Gamma}{\pi a^2 t} \int_o^t \int_o^a \int_o^{2\pi} \frac{r\ dr\ d\Theta\ dz}{r^2 + b^2 - 2br\cos\Theta + (h + z)^2}$$

This expression cannot readily be integrated in a closed form but for $b = 0$ (a special case for the field along the axis):

$$I_p = \frac{q\Gamma}{\pi a^2 t} \int_o^t \int_o^a \int_o^{2\pi} \frac{r\ dr\ d\Theta\ dz}{r^2 + (h + z)^2}$$

This may be integrated in the closed form:

$$I_p = \frac{q\Gamma}{a^2 t}\left[h \ln \frac{h^2}{h^2 + a^2} + (h + t) \ln \frac{(h + t)^2 + a^2}{(h + t)^2} + 2a\left(\tan^{-1}\frac{h + t}{a} - \tan^{-1}\frac{h}{a}\right)\right]$$

No reference to this derivation has been found in the literature.

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A Method of Measuring Nonlinear Distortion Caused by Photographic Lenses

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Photographic lenses are considered as spatial frequency filters whose performance may be described in terms of amplitude and phase response. Aberrations are then treated as frequency distortions. In order to study the uniformity of field of lenses in these terms, a square wave test chart of fixed frequency and sufficient extent to fill the field was prepared, and test photographs were made at such reduction that the spatial frequency in the image was about 16 lines/mm. The amplitude response for this frequency, measured as a function of field angle, was determined from microdensitometer traces. Phase characteristics of the lenses were determined by comparing the negative image with a suitable 16-lines/mm test grating. The amount of optical distortion can be estimated from phase data thus obtained.

A lens, today, is frequently considered to be a low-pass spatial frequency filter in analogy to the terminology in communication systems. The performance of a lens, therefore, can be characterized by its amplitude and phase response, supplementing or replacing the conventional resolving power measurements.* An example of the resolving power in the image field is shown in Fig. 1. The amplitude response of this lens on the optical axis is shown in Fig. 2. The response (in tangential and sagittal directions) varies from point to point in the image plane. The relation between the resolving power and the amplitude response is illustrated in Fig. 3. It we select one proper spatial frequency as a test target, the response at the frequency (dotted line in Fig. 3) may represent the uniformity of the performance of the lens. In particular, the cut-off frequency of the television system in Japanese studios is 8 megacycles, which corresponds to about 16 lines/mm. In order to measure the performance of a lens for TV use, the spatial frequency of the test pattern may be lower than 16 lines/mm when it is reduced to the image plane.

Definitions

If the amplitude response of the lens is unity and the phase is linear throughout the image field, and if the test target has only one spatial frequency component, the intensity distribution of the image when treated in one-dimensional space is as shown in Fig. 4A. The spectral components are shown in Fig. 4B. Owing to the image frame, the spectrum spreads to some extent.

If the amplitude response is uniform (but not unity) and the phase is linear throughout the image field, and if the test target is the same as before, the intensity distribution of the image and its spectral components are as shown in Fig. 5. In this case, the spectrum near the origin is the same as before, but the spectrum around the spatial carrier frequency is decreased to some extent due to the amplitude response at the spatial frequency. In this case, we can say that the lens contains a linear distortion (in the terminology in communication systems) in the spatial frequency domain.

On the other hand, if the lens has distortion in the usual optical sense of the word, the magnification of the image elements varies from point to point in the image plane. Objects of equal size imaged at different points off axis will apear to be of different image size. New components of the spatial frequency spectrum will appear, as shown in Fig. 6. In this case, the spectrum around the carrier is displaced towards the origin and the shape becomes asymmetric.

Finally, if the amplitude response is not uniform across the image field (but the magnification is uniform), this will give rise to new components in the spectrum. This is shown in Fig. 7. In this case, the spectrum around the carrier is symmetric. We wish to point out that the lens contains a nonlinear distortion in the spatial frequency domain when new components appear in the spectrum, compared to the aberration-free case.

Presented at the National Conference, Chicago, 28 October 1959. Received 1 September 1959; additional material received 22 October 1959.

* *Editor's note:* The following literature references are pertinent: P. Lindberg, *Optica Acta*, **1:** 80 (1954); E. Ingelstam, E. Djurle, and B. Sjogren, *J. Opt. Soc. Am.*, **46:** 707 (1956); R. L. Lamberts, *ibid.*, **48:** 490 (1958).

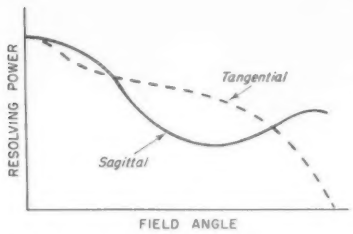

Fig. 1. An example of resolving power.

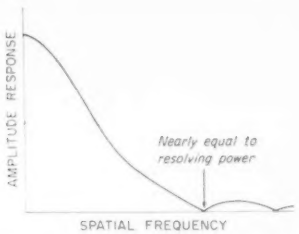

Fig. 2. An example of amplitude response on the optical axis.

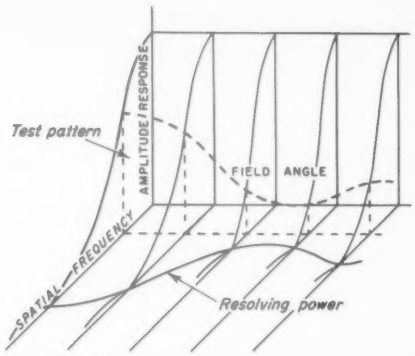

Fig. 3. A relation between resolving power and amplitude response.

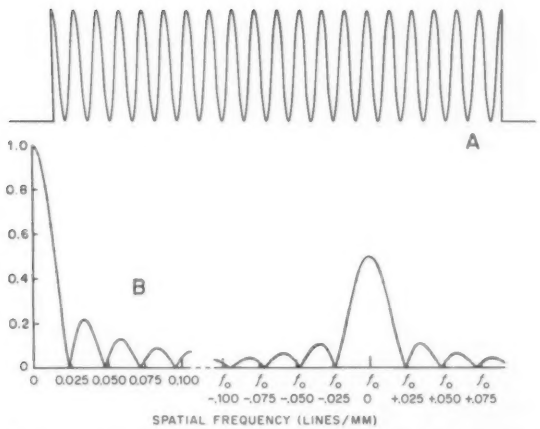

Fig. 4. A — Intensity distribution of image when amplitude response is 1.00 throughout image field and phase is linear. B — Corresponding spatial frequency spectrum.

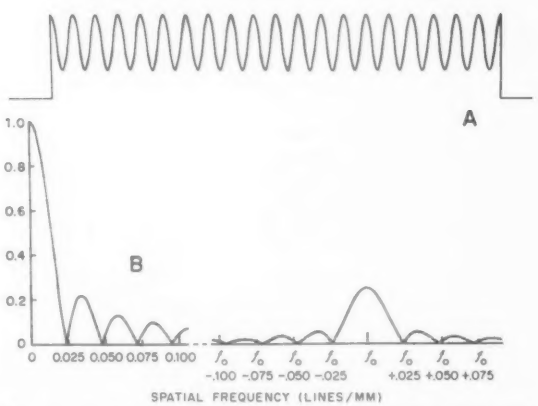

Fig. 5. A — Intensity distribution of image when amplitude response is 0.50 throughout image field and phase is linear. B — Corresponding spatial frequency spectrum.

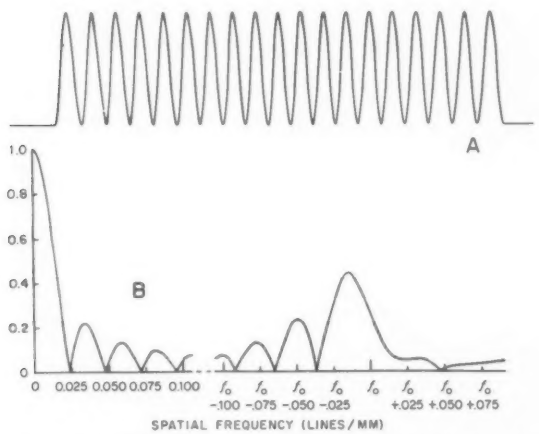

Fig. 6. A — Intensity distribution of image when amplitude response is 1.00 throughout image field and phase deviates from linear with third power of distance (π, at the edge). B — Corresponding spatial frequency spectrum.

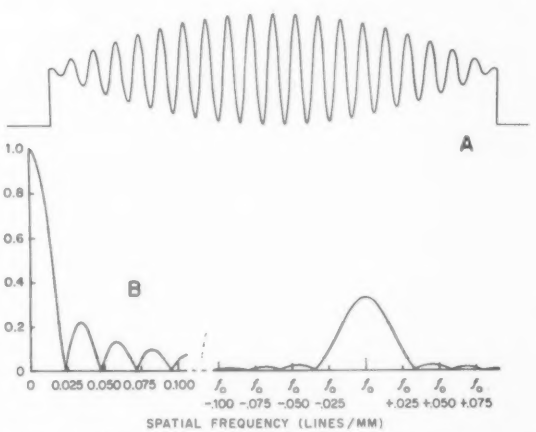

Fig. 7. A — Intensity distribution of image when amplitude response varies in proportion to square of distance and phase is linear. B — Corresponding spatial frequency spectrum.

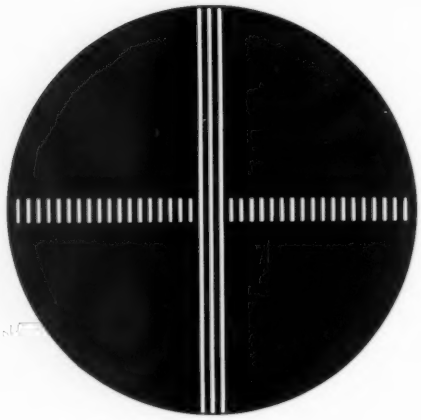

Fig. 8. Test pattern.

Method of Measurement

In order to characterize this nonlinear distortion, the amplitude and phase response of the lens must be measured at more than two points of the image plane. A complete analysis of the response for a wide range of frequencies at many points of the image field is very involved and time consuming. The task becomes very simple, however, when the measurement is restricted to one selected frequency, using a continuous pattern of this single spatial frequency as a test target.

We are using the pattern illustrated in Fig. 8. The length of the grid (as well as of the three parallel lines) is two meters. The grid lines represent a rectangular wave distribution of the brightness. Center-to-center distance of the lines (one period) is 3 mm. The target was made by a photographic method. When reproduced at a magnification (scale) of 1:50 it yields a spatial frequency in the image of 16.7 lines/mm, or a period of 60μ.

To be able to evaluate correctly the microdensitometer measurements of the photographic image, we printed a sensitometric step wedge on the same plate that carried the image of the test pattern. Panchromatic emulsions were used to make the test conform to the conditions of normal use. The dimensions of the effective slit area of the microdensitometer were 10μ by 30μ. Light reflected from the dark part of the test pattern can be neglected, since the ratio of the reflection coefficients of the dark part to the white part of the test pattern is less than 1.5%. The contrast of the intensity distribution of the image derived from these microdensitometer measurements is the amplitude response for the test frequency, as a function of field angle.

An example of the results obtained is shown in Fig. 9A. The lens is a Sonnar 50mm $f/1.5$; the image plane is at the best visual focus. The values shown in the curve include, of course, the response of the emulsion, which is almost uniform across the field. The true response of the lens can be found by dividing the output from the lens–emulsion combination by the known response of the film.

If we neglect the phase characteristics of the lens, the spatial frequency spectrum is computed directly from the curve of Fig. 9A. An example of tangential amplitude response at $f/1.5$ is shown in Fig. 9B. In this figure, the scale of the horizontal axis is one half that of the previous figures, and the effect of vignetting is also considered. The spectrum near the origin spreads out more than in the previous cases, and the fourth maximum is larger than the third maximum. With regard to the spectrum around the carrier, it spreads out much more broadly than before, and the second maximum decreases to about zero, but it is symmetric about the carrier.

The measurements of the phase characteristics were made by using the "beat" phenomenon occurring when two gratings (or similar periodic patterns) of slightly different frequency are superimposed.

A grating of constant frequency of 16.7 lines/mm (period = 60μ) was put in contact with the nega-

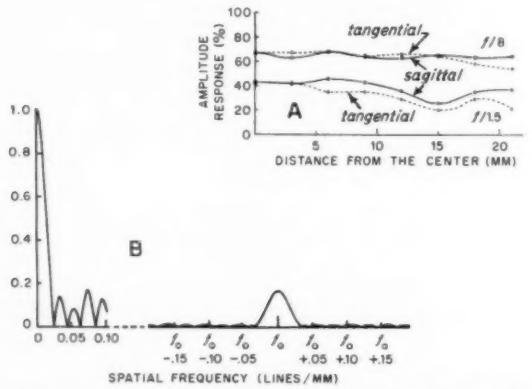

Fig. 9. A — Amplitude response as function of field for Sonnar 50mm lens. B — Spatial frequency spectrum corresponding to $f/1.5$ tangential response of A, and neglecting phase characteristics of lens.

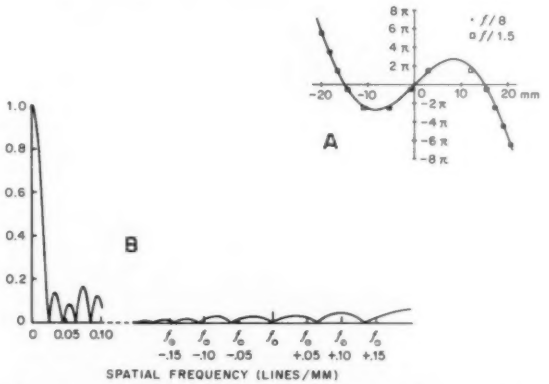

Fig. 10. A — Phase characteristics of Sonnar 50mm lens. B — Spatial frequency spectrum when phase shift is included in calculations.

tive, making sure, of course, that the lines on both parts were parallel. The density distribution of this sandwich was measured, and the shift of the image lines with respect to the grid lines was observed. An example of the phase characteristic is shown in Fig. 10A. The vertical axis indicates the phase difference between the negative and the grating. At the edge of the image plane, the beat stripes spread to the outer side. This means that the lens has positive distortion. If the curve is approximated by an equation of the form $ax + bx^3 + cx^5$, the values of the constants become $a = 0.492\pi$, $b = -0.00251\pi$, and $c = 1.39 \times 10^{-6}\pi$.

Usually the value of b corresponds to the distortion. In this case, it is approximated as about 3%, which is larger than the value derived from the graph.

In Fig. 10A, the round dots indicate the values at aperture $f/8$, the squares at $f/1.5$. The difference between these values is very small, indicating that the phase shift due to change of aperture is small.

If we consider the phase characteristics of the lens in addition to the amplitude response at aperture $f/1.5$, the spatial frequency spectrum becomes as in Fig. 10B. In this case the spectrum around the carrier spreads over such a wide range that we cannot show the whole spectrum.

The image of the test pattern in combination with the gray scale printed on it permits the measurement of still another characteristic of the lens, namely the vignetting. It was found that for this lens, the vignetting at the edge of the image plane was approximately 50%. Since the illumination of the test pattern is not uniform, this value was obtained from the ratio of the mean intensity at full aperture and at small aperture. Therefore this value does not contain the $\cos^4$ law.

The accuracy of this method is restricted by the accuracy of the photographic method, and it is estimated to be about 10%.

Conclusion

A method has been described which yields from a single exposure the amplitude response for a single selected frequency across the entire field, as well as the phase characteristics of the lens. With this method we can evaluate the nonlinear distortion of the lens.

1960 Annual Conference

9 to 13 May

Miramar Hotel, Santa Monica, California

THE ADVANCE PROGRAM appears on pages 122–128.

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PHOTOGRAPHIC SCIENCE AND ENGINEERING
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Photographic Problems Associated with the Construction of a Large Computer Memory

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Megabit photographic memory with random access in a few microseconds to a seventy-bit word has been constructed for use in a digital computer. The nature of the memory system is presented. The optical discrimination ratio is discussed as a function of the various optical and photographic problems which affect performance. Test methods used on principal optical components are presented and sample results shown. The construction of the photographic elements in a closed-loop beam-positioning system is discussed in terms of the photographic procedures used to control precise (±0.0003-in.) image location.

An experimental electronic switching system for connecting telephones in a central office has been designed and built and is currently being installed in Morris, Ill. This system has a switching network under the control of an information processing unit. The information processing unit consists of transistor and diode logic and temporary and photographic memory units. The general organization of the system and the design parameters of the photographic storage system are presented in detail in the literature.[1-3] This paper will discuss some of the photographic factors important to information storage.

The fundamental organization of a single channel of a flying spot store is shown in Fig. 1. An optical channel consists of an objective lens, a photographic plate, a condenser lens, and a photomultiplier tube. A cathode-ray tube is used as a light source for writing and reading stored information. The objective lens brings the cathode-ray tube spot to focus at the photographic plate. The condenser lens images the stop of the objective lens onto the photocathode of the photomultiplier.

The organization of the store is shown in Fig. 2. Random access circuitry positions the spot on the cathode-ray tube. A light intensity stabilizer, input address registers, and output information registers are some of the additional functional components of the store.

Multiple optical channels are used to build up the total capacity which is the product of the number of addresses on the cathode-ray tube and the number of channels in the store. The address of the spot on the cathode-ray tube is the binary address in rectangular coordinates of the spot. A word is formed by reading out one bit from each channel. The total capacity of current systems is limited by the resolution characteristics of the cathode-ray tube and present systems with high-speed access are limited to the order of 10^7 bits.

Access to an address is gained through a closed-loop beam-positioning system. This information access contains several optical channels from which can be read the horizontal and vertical positions of the light spot on the cathode-ray tube. One channel is required for each binary bit needed to define the beam position. Figure 3, a rear view of an optical assembly, shows the binary code plates and the relative organization of channels for a 256^2 raster. In operation, the input registers are set to the desired address, which is then compared by digital logic circuitry with the current address of the spot. An error signal is generated which is used to drive the deflection circuits of the cathode-ray tube. When the spot reaches the desired address, the error signal vanishes and the beam comes to rest.

The store is used to write its own information storage areas. This requirement is adopted to

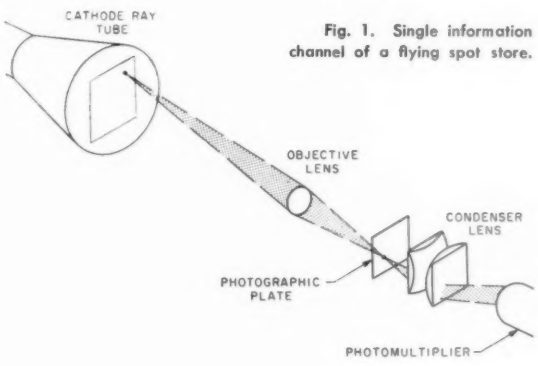

Fig. 1. Single information channel of a flying spot store.

Presented at the National Conference, Chicago, 26 October 1959. Received 12 October 1959.

1. A. E. Joel, Jr., *Bell System Tech. Jour.*, **37**: 1091 (1958).
2. C. W. Hoover, Jr., R. E. Staehler, and R. W. Ketchledge, *ibid.*, 1161.
3. M. B. Purvis, G. V. Deverall, and D. R. Herriott, *ibid.*, **38**: 403 (1959).

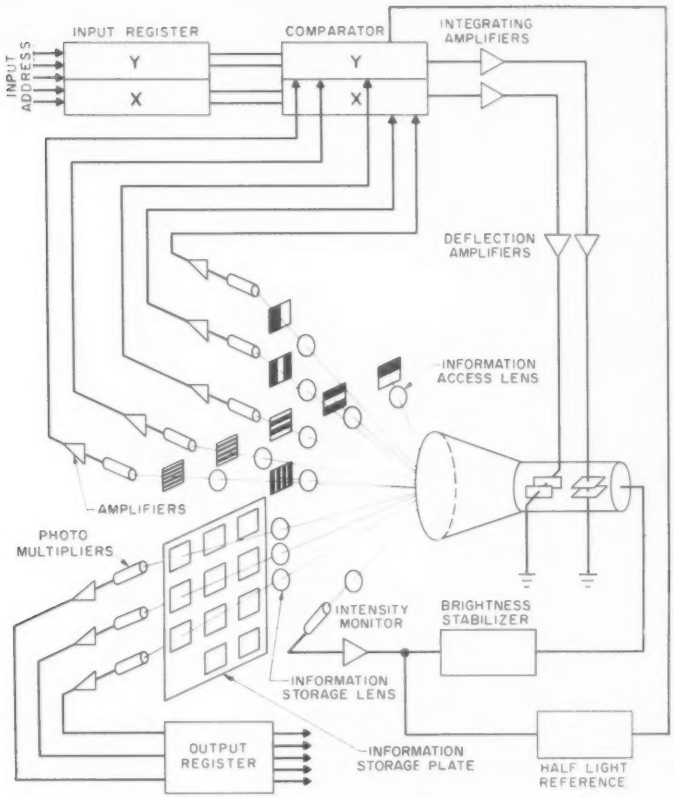

Fig. 2. Organization of a flying spot store.

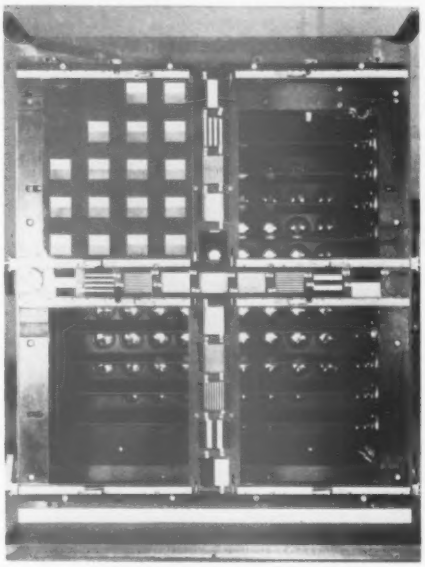

Fig. 3. Rear view of an optical assembly.

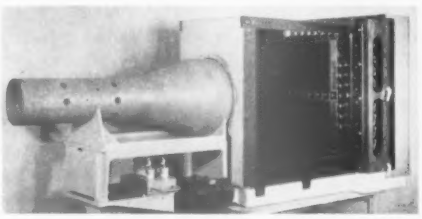

Fig. 4. Side view of an optical assembly.

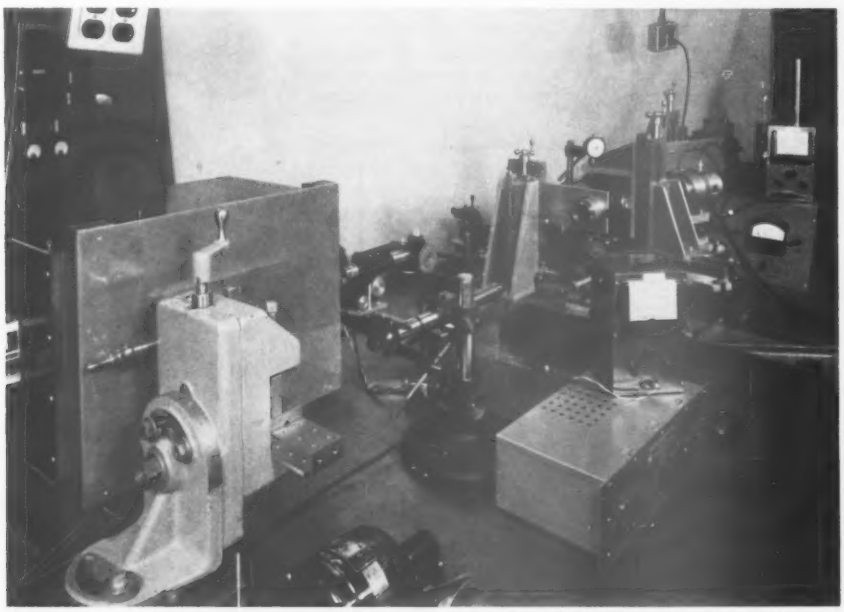

Fig. 5. Experimental setup for determining optical discrimination ratio.

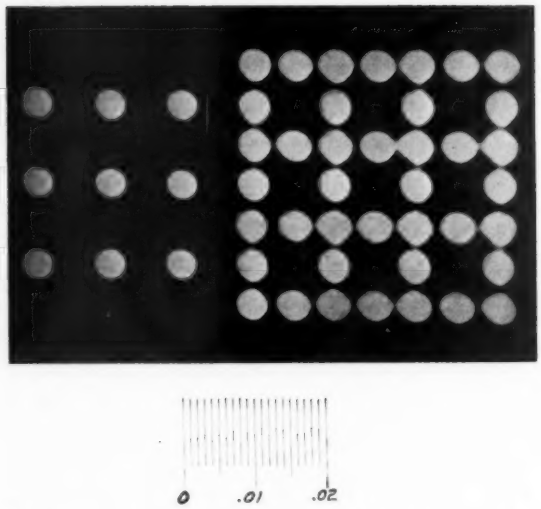

Fig. 6. Enlargement of an array used to determine optical discrimination ratio.

reduce the distortion and focal length tolerances on the objective lenses to values compatible with low-cost production. In the writing operation all channels except one are closed by shutters and the plate in that channel is exposed. Because of the necessity to keep the spot on the cathode-ray tube for positioning, the exposure of individual bits is accomplished by the dwell time at an address. Emulsions of sufficient inertia are used to protect from exposure those address areas where no exposure is wanted. When one channel has been exposed, the shutters are changed to open another channel, and the information to be encoded in that area is displayed on the cathode-ray tube. When all the channels on a plate have been exposed, the plate is removed, processed, and reinserted in the store. The store is then ready to operate.

Figure 3 shows some general features of an optical system. The objective lenses, $f/8$ at 4-to-1 reduction, and rear shutters may be noted. A storage plate with a test pattern is shown in reading position in one quadrant. The format of the beam positioning plates is visible, and the condenser lens assembly is shown on a bench in the background. Figure 4 shows a side elevation of an optical assembly.

With this general picture of the system format the details of the photographic parameters may be discussed.

Information Storage

Optical Discrimination Ratio

A single parameter which can be used to evaluate the entire optical and photographic part of the flying spot store has been defined. It is called the optical discrimination ratio (ρ) and is expressed by the equation:

$$\rho = \frac{S_{1,\,\min} - S_{0,\,\max}}{S_{0,\,\max}}$$

where $S_{1,\,\min}$ is the relative amplitude of the minimum "1" in the channel, and $S_{0,\,\max}$ is the relative amplitude of the maximum "0" in the channel.

This parameter is perhaps best understood by considering an experiment to measure it.

A cathode-ray tube, lens, photographic plate, condenser lens, and photomultiplier tube are set up to simulate one channel of a flying spot store, Fig 5, and an array of spots are written in the form shown in Fig. 6. In this case, the plate has been chemically reversed. The array consists of two parts. The clear spots on the left are surrounded by opaque emulsion, and when they are read out, they will give the $S_{1,\,\min}$ or minimum-one signal. The boxes on the right have clear spots completely surrounding an opaque area where a spot has been omitted. The readout of this opaque area will give the $S_{0,\,\max}$ or maximum-zero signal.

The performance of all the elements in the optical path from the cathode-ray tube to the photomultiplier may be evaluated in terms of this single parameter, and the combination of the performance curves of the parts may be used to predict the operation of the system.

Optics

For a lens which is well corrected, particularly for coma and astigmatism, the image of a point of light is symmetrical over the field of the lens. It has been found that the energy distribution in the image can, for the application discussed here, be approximated sufficiently well by a Gaussian distribution. This approximation greatly simplifies the application of mathematics to the problem, since the energy distribution in the cathode-ray tube (CRT) spot is substantially Gaussian and, therefore, the energy distribution in the image of the CRT spot is Gaussian:

$$I = I_o\, e^{-\frac{r^2}{2\sigma^2}}$$

where r is the radius and σ is the standard deviation; and

$$\sigma^2_{\text{image}} = \sigma^2_{\text{lens}} + \left(\frac{\sigma_{\text{CRT}}}{m}\right)^2$$

where m = reduction ratio of the lens.

Photography

The photographic problem associated with the storage of information in binary form is in many ways a simple one, since it is desired that the photographic image be either opaque or clear with as little gray area as possible. In this application, the requirements of high density (>2), high gamma (>5), and good dimensional stability are best met by the use of reversed (positive) plates. A positive plate also has the advantage over a negative plate of reducing the stray light which passes through the plate and raises the background level as seen by the

photomultiplier. In terms of the optical discrimination ratio, the positive versus negative plate results in improvement by a factor of two.

The speed requirement on the emulsion is not a serious one. Emulsions of the Kodak Microfile type have been found quite satisfactory. The emulsion used should, of course, have a spectral response comparable to the spectral energy distribution in the cathode-ray tube phosphor. If P-16 phosphor is used, for example, an orthochromatic-type emulsion provides a good match.

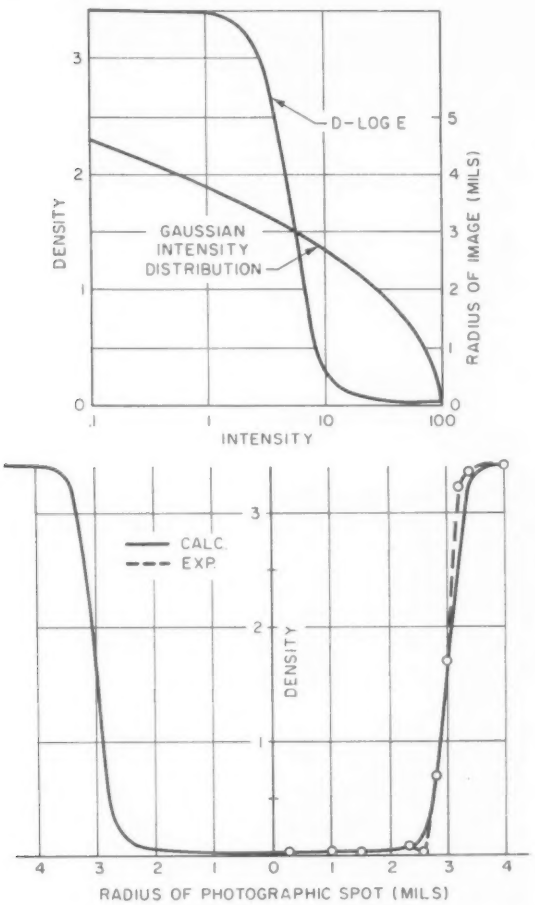

Fig. 7. Density well produced in reversed photographic plate by cathode-ray tube spot compared with that calculated from a Gaussian image. Exposure time, 500 μ sec; σ_{image} = 1.25 mils.

A graph of D-log E for one emulsion is shown in Fig. 7. Superimposed on it is a plot of the intensity distribution in a Gaussian image. The resultant calculated density trace of the image is shown below, and compared with it is an experimentally determined curve. The gamma of this particular emulsion is 7, and the maximum density is 3.4. If an emulsion of lower gamma had been used the "density well" would be less square and, for a given spot spacing, the optical discrimination ratio would be relatively lower, due to the influence of adjacent spots. It is also obvious from an examination of the figure that it is desirable to have as sharp a toe on the curve as possible.

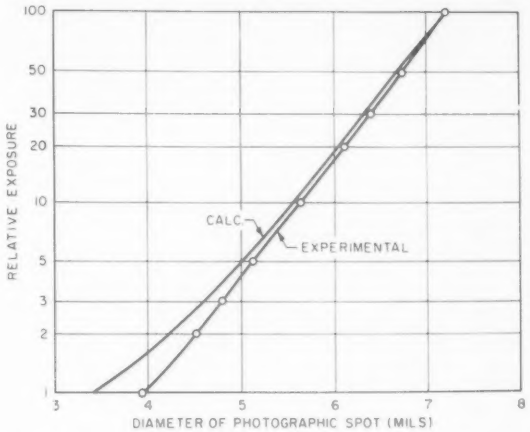

Fig. 8. Photographic spot size vs. exposure for cathode-ray tube spot.

The application of the usual macroscopic photographic test methods to the particular problem of information storage on the photographic plate must be interpreted with caution, since the images are quite small and consequently microphenomena such as adjacency effects play a considerable role.

Figure 8 shows a graph of the photographic spot size vs. the exposure and compares this curve with a calculated curve obtained by assuming the intensity distribution in the image to be Gaussian. Figure 9 shows how the optical discrimination ratio varies

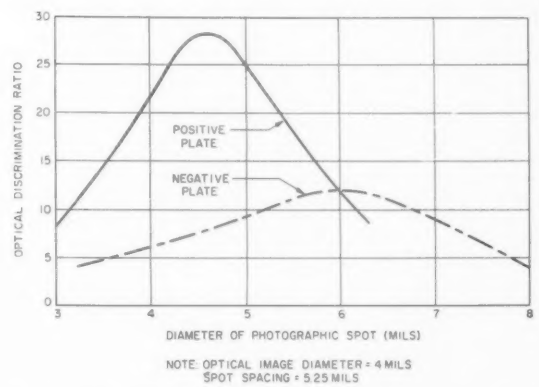
OPTICAL DISCRIMINATION RATIO
POSITIVE PLATE
NEGATIVE PLATE
DIAMETER OF PHOTOGRAPHIC SPOT (MILS)
NOTE: OPTICAL IMAGE DIAMETER = 4 MILS
SPOT SPACING = 5.25 MILS

Fig. 9. Optical discrimination ratio vs. photographic spot size for a fixed cathode-ray tube spot size and fixed spot spacing.

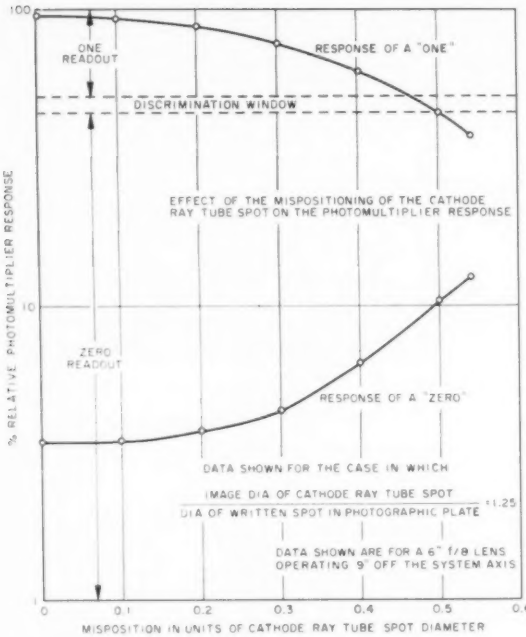
100
10
1
% RELATIVE PHOTOMULTIPLIER RESPONSE
ONE READOUT
RESPONSE OF A "ONE"
DISCRIMINATION WINDOW
EFFECT OF THE MISPOSITIONING OF THE CATHODE RAY TUBE SPOT ON THE PHOTOMULTIPLIER RESPONSE
ZERO READOUT
RESPONSE OF A "ZERO"
DATA SHOWN FOR THE CASE IN WHICH
IMAGE DIA OF CATHODE RAY TUBE SPOT / DIA OF WRITTEN SPOT IN PHOTOGRAPHIC PLATE = 1.25
DATA SHOWN ARE FOR A 6" f/8 LENS OPERATING 9° OFF THE SYSTEM AXIS
0
0.1
0.2
0.3
0.4
0.5
0.6
MISPOSITION IN UNITS OF CATHODE RAY TUBE SPOT DIAMETER

Fig. 10. Effect of mispositioning of cathode-ray tube spot on photomultiplier response.

with photographic spot size for a fixed size CRT spot and a fixed spot spacing.

Another problem affected by the photography is that associated with the permissible tolerances in mispositioning of the CRT spot during readout. Figure 10 shows what accuracy must be achieved to give a satisfactory optical discrimination ratio.

Access System

One of the more interesting problems in implementing a flying spot store is the construction of the access system. This access system as implemented optically and photographically represents the application of standard art with strict attention to detail. The problem is to provide a discrete address at the object plane for each spot on the raster. This is accomplished by providing two coordinate sets of binary code plates for the space division of the object plane.

The optical-photographic elements of the access system must meet three requirements: (*a*) geometry; (*b*) crossover; and (*c*) redundancy.

By geometry is meant the discrimination of the address to a satisfactory tolerance. The photographic tolerance for location of edges is of the order of 0.0002 in. At this tolerance level, the practical method of maintaining geometry is to establish this at the object plane through a series of ruled masters, and to photograph each code plate through the lens with which it will be read. This procedure takes into account the individual distortion and focal length variations of the objective lenses used. This in turn relaxes the tolerances on the lenses to a reasonable level. The location of the code plate is monitored in the critical axis only. Mispositioning along the bar introduces no error since the code plate is continuous beyond the desired address area.

The photographic requirements are not severe. One desires maximum contrast, densities well above 2 in the opaque areas, and an emulsion well behaved in processing. Kodalith Ortho has proven to be a relatively good selection for this application. The basic problem is that of exposure, which is, of course, critical in holding the alternate black and clear bars equal in width. Figure 11 shows a code plate produced for use in a store. The apparent sharpness of the lines is belied by Fig. 12, an enlargement of a section of an edge from the plate. It is evident that some method of determining a standard of sharpness for the edge as well as the geometric location of the edge is necessary. Figure 13 shows microdensitometer traces across an edge in comparison with a razor blade. Experience has

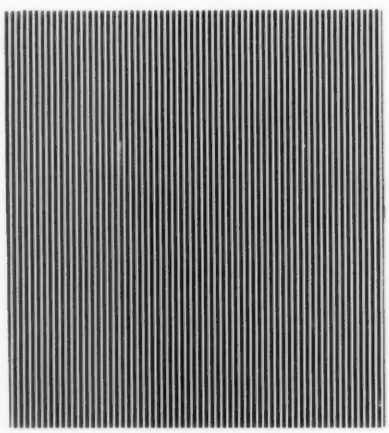

Fig. 11. Code plate.

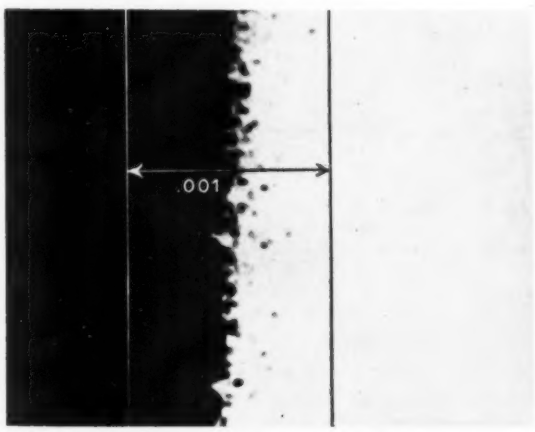

Fig. 12. Enlargement of a section of an edge from Fig. 11.

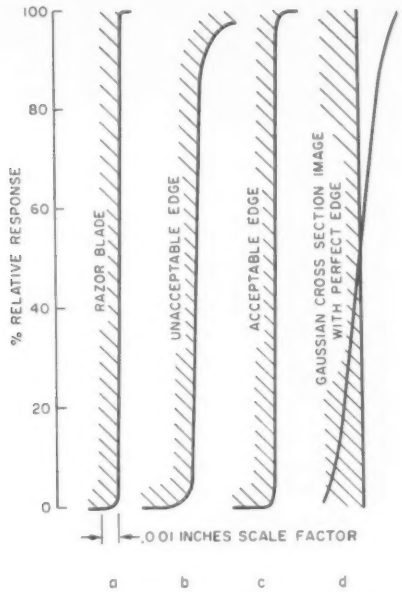

Fig. 13. Photomultiplier response vs. position with respect to an edge. Curves a, b, and c are microdensitometer traces. Curve d is the crossover of a Gaussian image with a perfect edge.

shown that the edges can be held to a slope of one-half that for the razor blade edge as measured on our microdensitometer. The scanning aperture of the instrument for these tests was 10μ. The width of the bar is taken between points for which this microdensitometer output signal is half amplitude. Thus, by equipping the microdensitometer table with a dial indicator sensitive to 0.0001 in., it is possible to determine bar widths on a repetitive basis independent of the operator.

Tests were conducted to ascertain the influences of development time on the bar width. The results

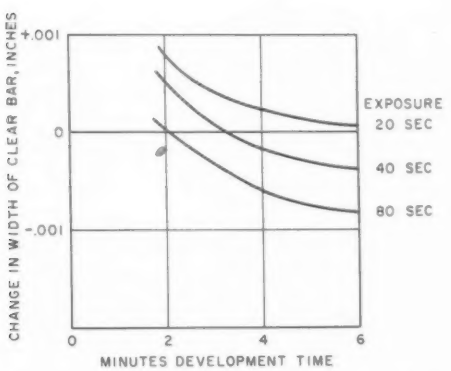

Fig. 14. The effect of development time on bar width for three exposure times.

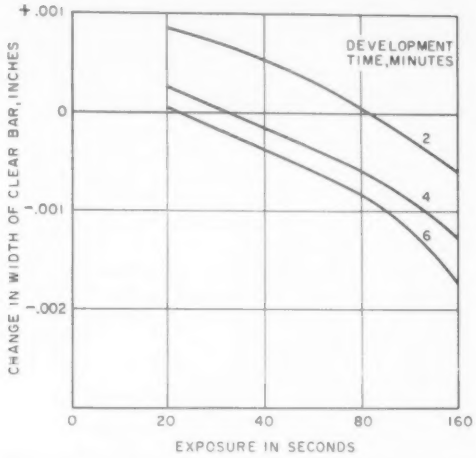

Fig. 15. The effect of exposure time on bar width for three development times.

of such tests are shown in Fig. 14, and indicate that the effect is small with processing times beyond 4 min. Having fixed the processing procedure, the bar width variation with exposure time was ascertained for the spectral distribution of interest. Results are shown in Fig. 15. The small though continuous change in bar width with exposure time is evident. Finally, a check on the obtained density was made by plotting data from all the plates (see Fig. 16). For the practical exposure and development times, the density is greater than the desired value of 2.

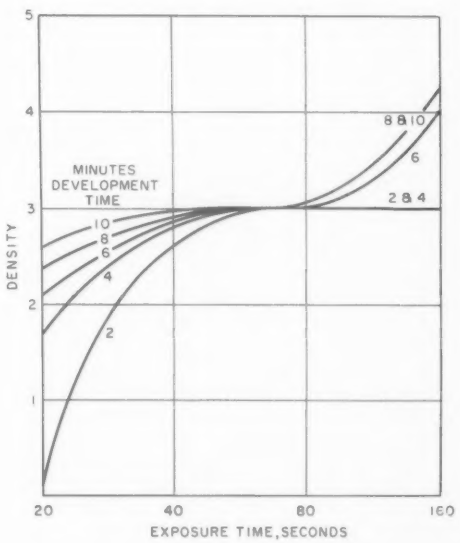

Fig. 16. Density vs. exposure time.

The second major consideration in the access system construction is that of crossover, the rate of change of light level with motion of the spot across the bar edge. The stability-speed character of the access system is limited by the crossover characteristic achieved photographically. Where geometry demands a high contrast, the crossover demands a continuous tone. In practice, the result desired is achieved by taking advantage of the longitudinal chromatism characteristic of the lens. By photographing the code plate in green light for which the focal position of the lens is set, the sharp edges demanded by geometry are achieved. Later, in operation, the plate is scanned with the blue spectrum of P-16 and the edge is out of focus, thereby producing the desired crossover required for stability and speed.

Redundancy is used to protect against positioning errors due to small blemishes in the edges, due either to digs in the master code plates or dust in the plate.

Redundancy is achieved by the addition of a weak, ophthalmic cylinder to the objective lens. The cylinder lens is used in the no-power axis so that with low prism and centering variations achieved through close tolerances, the resulting energy distribution is still roughly Gaussian in cross section through the line image. The axis of the cylinder lens must be closely aligned with the code plate bars during photography to avoid smearing the bar edge in the same plane. Microscopic examination of the line image, followed by comparison of microdensitometer traces of the developed photographic plate with the razor edge, achieve the necessary degree of control. The crossover of a line of light of Gaussian cross section with a perfectly sharp servo edge is shown in Fig. 13.

Conclusions

A large electronic information processing unit for use in telephone switching has been built. It uses a semipermanent memory which stores binary information on photographic plates. The commercially available high-contrast emulsions processed in a conventional way have been found very suitable both for information storage and for construction of the access system.

Acknowledgments

The electronic switching system development program is under the general direction of C. A. Lovell and R. W. Ketchledge. R. E. Staehler directs the development of storage systems. The advice and assistance of members of the Research Laboratories of Eastman Kodak Co. on the photographic problem is gratefully acknowledged.

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Influences of Some Addition Agents on the Color of Developed Silver from Liquid Photographic Emulsion

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The influence of alkyl homologues of 6-alkyl-7-hydroxy-5-methyl-1,3,4-triazaindolizine, 2-alkyl-1,3,4-oxadiazoline-5-thione, and 2-alkyl-5-amino-1,3,4-oxadiazole on the color of the developed silver image was investigated with a liquid silver chloride emulsion developed by a dilute Phenidone – hydroquinone developer. Each agent was added in various amounts to samples of the emulsion prior to development. Development was stopped and the emulsion was fixed by adding first a small portion of a stop solution and then a fixer. Spectrophotometric density curves of the silver dispersions were obtained. The color became more blue-black with increasing number of carbon atoms in the alkyl group of the triazaindolizine but with decreasing number of carbon atoms in the alkyl group of the oxadiazoline-5-thione. The most effective oxadiazole homologue for the production of a blue-black tone was the nonyl.

It is well known that certain compounds show marked effects on the color of developed silver images if they are added to emulsions or developers. Some of them can shift image tone toward blue-black and are useful in the photographic industry. These compounds have been disclosed in several patents and published papers.[1,2]

Earlier, one of the authors[3] described the influence of the chain length of the alkyl group in a substituted active compound on the color shift of the silver developed in chloride or chlorobromide papers. For example, in the alkyl homologues of S-alkylmercaptobenzothiazole and S-alkylmercaptobenzimidazole, the blue-black toning tendency grows stronger when the alkyl group is changed from methyl, to ethyl, to allyl in turn. On the other hand, among N-alkyl homologues of benzothiazoline-2-thione, methyl, ethyl, and allyl derivatives show equal and very strong blue-black toning effects.

Recently E. J. Birr[4] also reported that among the alkyl homologues of 5-alkyl-7-hydroxy-1,3,4,-triazaindolizine, the *n*-amyl compound had the maximum effect in shifting image tone toward blue-black in the development of a chloride paper.

The usefulness of the liquid emulsion technique for testing the effect of additions to emulsions has been demonstrated in a previous paper,[5] and many classes of compounds have already been tested with this technique.

There are some difficulties in measuring the spectrophotometric density of silver deposits on a paper with enough precision to specify the color of a print, and it is easier to determine spectrophotometric densities of a liquid dispersion of colloidal silver. This is why we used liquid emulsions instead of coated papers.

The present paper refers only to the behavior of alkyl homologues of three groups of compounds: 6-alkyl-7-hydroxy-5-methyl-1,3,4-triazaindolizines, 2-alkyl-1,3,4-oxadiazoline-5-thiones, and 2-alkyl-5-amino-1,3,4-oxadiazoles (22 compounds in all). These compounds were added to the liquid emulsions to determine their effect on the color of the developed silver. Very good correlation was found between the color of the developed silver and the number of carbon atoms in the alkyl group.

The effects of chain length of these alkyl homologues on the antifogging property and the acceleration or retardation of development, and the effect of duration of development on the color shift were also investigated. The results of these investigations are not, however, included in this paper.

Experimental Procedure

The experimental procedure used in this investigation is almost identical with that reported in the previous paper;[5] it is cited only briefly here for the convenience of the reader.

A silver chloride emulsion was prepared according to the following formula:

I	Gelatin	9.0 grams (55°C)
	Water	120 ml

Presented at the National Conference, Chicago, 29 October 1959. Received 1 September 1959.

1. Cf. C. E. K. Mees, *The Theory of the Photographic Process*, 2nd ed., Macmillan, New York, 1954, p. 755.
2. Y. Ohyama, *Rikagaku Kenkyujo Iho*, **22:** 483 (1943); *ibid.*, **23:** (*Ka.*) 7 (1944); ——, *Nippon Shashin Gakkai Kaishi*, **9:** 1, 57 (1943) (all in Japanese).
3. ——, *Bull. Soc. Chem. Japan*, **25:** 18 (1952).
4. E. J. Birr, *Z. wiss. Phot.*, **50:** 124 (1955).
5. T. Iwasaki, Y. Ohyama, and K. Futaki, *Bull. Soc. Sci. Phot. (Japan)*, *in press.*

TABLE I

Spectrophotometric Densities and Color Ratio for Silver Developed with Various Amounts of 6-*n*-hexyl-7-hydroxy-5-methyl-1,3,4-triazaindolizine Present

Amount added, mole/mole AgCl	Density (D) at wavelength of:							Color ratio D(400)/ D(700)
	400	450	500	550	600	650	700 mμ	
None	1.070	0.885	0.769	0.709	0.664	0.653	0.650	1.65
1×10^{-2}	1.036	0.865	0.770	0.721	0.698	0.697	0.708	1.46
5×10^{-2}	0.920	0.865	0.815	0.780	0.760	0.762	0.770	1.19
5×10^{-1}	0.820	0.845	0.855	0.850	0.845	0.840	0.840	0.975

II { $AgNO_3$ ..... 6.0 grams (55°C); Water ..... 24 ml

III { NaCl ..... 2.7 grams (45°C); Water ..... 24 ml

IV { Gelatin ..... 15.0 grams (55°C); Water ..... 100 ml

Solution II was poured into Solution I with stirring, and 30 sec later Solution III was added. After 60-min digestion at 55°C, Solution IV was added, and after 10-min further digestion (70 min from the beginning), the emulsion was cooled down to 25°C and diluted with water to 600 ml.

A portion of this emulsion was diluted 50 times with a 1% solution of gelatin and 4 ml of the diluted emulsion was mixed with 0.2 ml of a solution of one of various agents in methanol. (The 0.2 ml of solution was replaced with 0.2 ml of methanol in the control.) The complete solution was kept at 25°C for 30 min in a weighing bottle 4 cm in diameter and 4 cm high and then exposed in the liquid state for 5 min to a 100-w tungsten lamp operated at 85 v. The intensity of illumination at the exposing surface of the emulsion was about 133 lux.

After exposure the diluted emulsion was developed in the liquid state for 10 min with the addition of 4 ml of a diluted developer. The developer was made up of 7 ml of the following stock solution added to 93 ml of 1% gelatin solution:

Developer (Stock solution)

Sodium sulfite anhydrous ..... 50 grams
Hydroquinone ..... 12 grams
Sodium carbonate anhydrous .. 60 grams
Phenidone ..... 0.5 grams
Potassium bromide ..... 2.0 grams
Water to make 1.0 liter

The development was stopped by adding 1 ml of 2.5*N* acetic acid, and the emulsion was fixed with 1 ml of a diluted solution (25 times) of the following acid fixer:

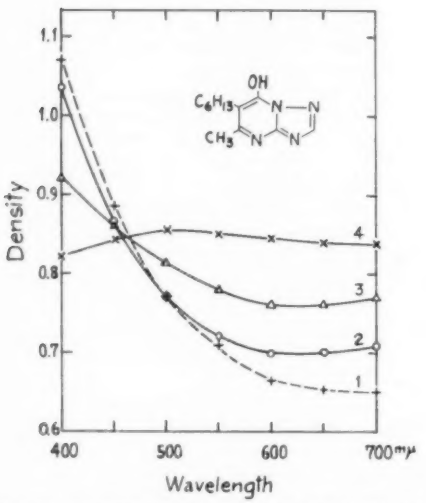

Fig. 1. Spectrophotometric curves for silver developed with various amounts of 6-n-hexyl-7-hydroxy-5-methyl-1,3,4-triazaindolizine present. Concentrations in mole/mole AgCl: Curve 1 — control; Curve 2 — 1×10^{-2}; Curve 3 — 5×10^{-2}; Curve 4 — 5×10^{-1}.

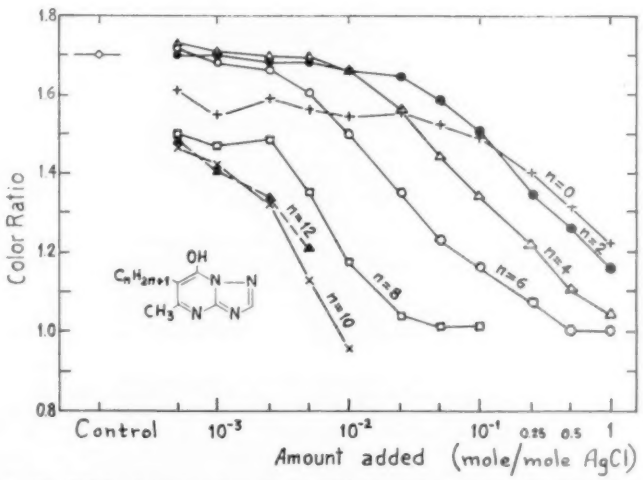

Fig. 2. Relation between color ratio and added amount of various alkyl homologues of 6-alkyl-7-hydroxy-5-methyl-1,3,4-triazaindolizines.

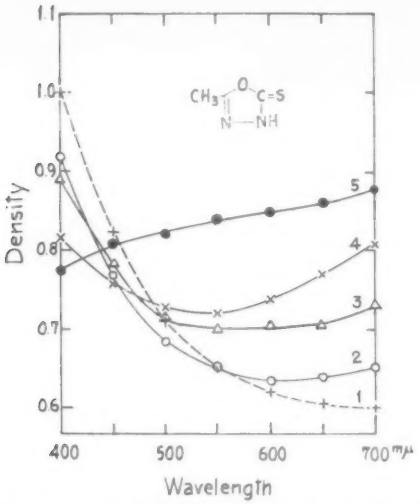

Fig. 3. Spectrophotometric curves for silver developed with various amounts of 2-methyl-1,3,4-oxadiazoline-5-thione present. Concentrations in mole/mole AgCl: Curve 1 — control; Curve 2 — 1×10^{-3}; Curve 3 — 2.5×10^{-3}; Curve 4 — 5×10^{-3}; Curve 5 — 1×10^{-1}.

Fixer (Stock solution)

Sodium thiosulfate . . . . . 200 grams
Potassium metabisulfite . . . . . 25 grams
Water to make 1.0 liter

After 30 min the spectrophotometric density of the solution (colloidal suspension of the developed silver) was measured in a 1-cm thick cubette using a Beckman-type spectrophotometer.

A solution prepared in the following manner was used as a blank: A mixture of 4 ml of 1% gelatin solution, 0.2 ml of methanol, and 4 ml of developer was allowed to stand for 10 min at 25°C; 1 ml of 2*N* acetic acid and 1 ml of fixer were then added.

Since it must be assured that the dispersion of the developed silver is free from colored products other than silver grains after treatment, the spectrophotometric density of the supernatant liquid after removal of the silver deposit by centrifuging was measured. The density difference between the blank and this liquid at any wavelength did not exceed 0.011, which is negligible for the purpose of the present experiments.

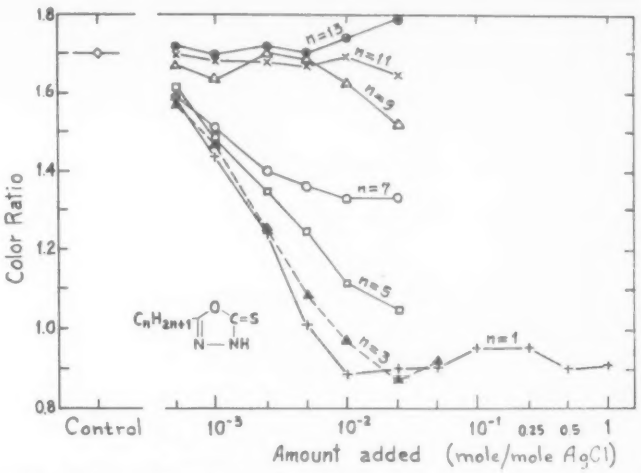

Fig. 4. Relation between color ratio and amount of various alkyl homologues of 2-alkyl-1,3,4-oxadiazoline-5-thiones added.

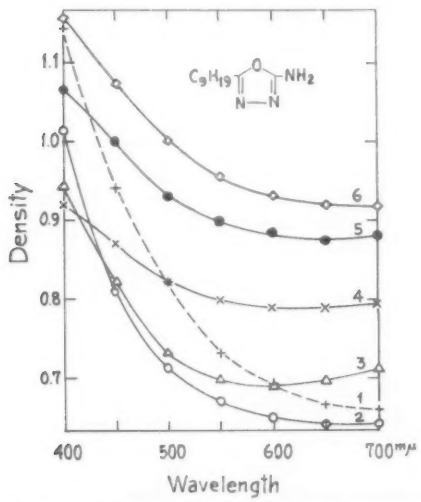

Fig. 5. Spectrophotometric curves for silver developed with various amounts of 2-n-nonyl-5-amino-1,3,4-oxadiazole present. Concentrations in mole/mole AgCl: Curve 1 — control; Curve 2 — 1×10^{-3}; Curve 3 — 1×10^{-2}; Curve 4 — 1×10^{-1}; Curve 5 — 2.5×10^{-1}; Curve 6 — 5×10^{-1}.

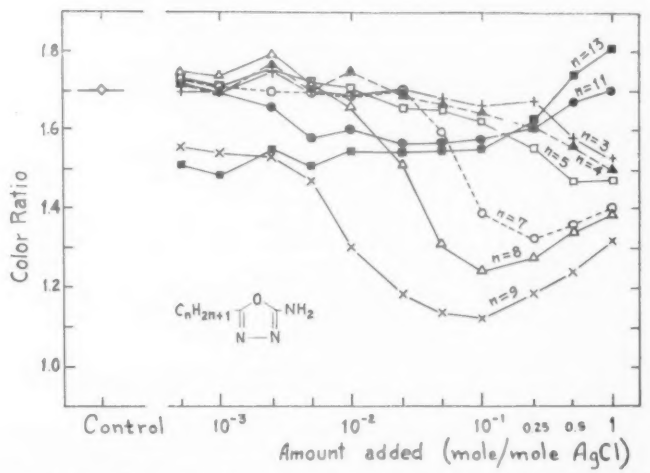

Fig. 6. Relation between color ratio and amount of various alkyl homologues of 2-alkyl-5-amino-1,3,4-oxadiazoles added.

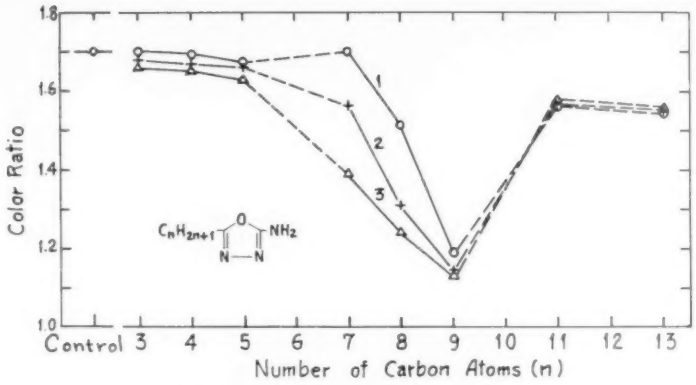

Fig. 7. Relation between color ratio and number of carbon atoms in the alkyl substituents of 2-alkyl-5-amino-1,3,4-oxadiazoles at three levels of concentration. Concentrations in mole/mole AgCl: Curve 1 — 2.5×10^{-2}; Curve 2 — 5×10^{-2}; Curve 3 — 1×10^{-1}.

Results and Discussion

6-Alkyl-7-hydroxy-5-methyl-1,3,4-triazaindolizines

As a typical example of these homologues, the spectrophotometric densities of the developed silver dispersions containing the *n*-hexyl derivative are shown in Table I and Fig. 1. The curve for the control (broken line) shows strong absorption at shorter wavelengths and in fact the color of the dispersion is a yellowish brown-black. With increasing concentration of this compound the photometric density at longer wavelengths increases, with the color shifting to blue-black.

According to the proposal of James and Vanselow,[6] the ratio of the density measured at 400 mμ to that at 700 mμ was taken as an indication of the "color" of the silver dispersion, because there is no distinct maximum between these wavelengths.

The "color ratio" thus calculated, however, varies from one experiment to another because of the inevitable variation of conditions. To eliminate this slight variation and to smooth out the data obtained, adjusted color ratios were used for comparison of the results. This is accomplished by adjusting the ratio of the control to 1.70.

The duration of development affects the color ratio only during the early stages of development. The "color ratio" generally reaches a limiting value within 5 min; 10-min development suffices in all cases under the experimental conditions used.

The effect of alkyl homologues of the triazaindolizines on the "color ratio" is shown in Fig. 2. The color of the developed silver shifts markedly towards blue-black with increasing amount of added agent and also with increasing number of carbon atoms in the alkyl groups of the homologues. The correlation between the number of carbon atoms in the alkyl groups and the color ratio is excellent. The strongest blue-black toning effect is obtained when the alkyl substitution is decyl.

2-Alkyl-1,3,4-oxadiazoline-5-thiones

Spectrophotometric densities of the developed silver with increasing amount of 2-methyl-1,3,4-oxadiazoline-5-thione are shown in Fig. 3. The influences of the amount of compound added and the number of carbon atoms in the alkyl groups on the color ratios in this case are shown in Fig. 4. As indicated in this figure the methyl derivative shows the strongest blue-black toning effect among the homologues and the color of the developed silver shifts toward warm-black with increasing number of carbon atoms in the alkyl groups, which is contrary to the case of the triazaindolizines mentioned above.

2-Alkyl-5-amino-1,3,4-oxadiazoles

Figure 5 is a typical example in this series of experiments. The tendency of the absorption by the developed silver to increase at longer wavelength with increasing concentration of 2-*n*-nonyl-5-amino-1,3,4-oxadiazole in the emulsion is not so manifest as in the previous cases (Figs. 1 and 3). The relation between the color ratio and the added amount of various alkyl homologues of 5-amino-1,3,4-oxadiazoles is shown in Fig. 6.

The maximum blue-black toning is observed when the number of carbon atoms in the alkyl groups reaches 9 (i.e. *n*-nonyl) and afterward the color of the developed silver shifts to a warmer tone, as is more clearly shown in Fig. 7.

The effects of the number of carbon atoms in the alkyl groups on the color of the developed silver seems to be very confusing. In our opinion, however, the results probably can be explained rationally on the basis of properties of the compounds such as solubility in the developer or adsorbability on the surface of silver halide, which change regularly with the number of carbon atoms in the alkyl groups. There are probably some optimum values in this series of substances which will correlate with their chemical constitutions.

Acknowledgments

The authors are indebted to Senji Tosa for his cooperation in the preparation of alkyl homologues of the triazaindolizines; also they wish to express their thanks to Katsua Hohjoh for his assistance in carrying out the many laboratory experiments.

6. T. H. James and W. Vanselow, *Phot. Sci. & Eng.*, **1**: 104 (1958).

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Photographic Development by Hydroquinone Compounds with Positively Charged Groups

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Positively charged substituents on hydroquinone developers considerably decrease the induction period of photographic development. This decrease is interpreted in terms of a diminished electrostatic repulsion of the negative potential barrier of the silver halide particles upon these developers. Chromatographic elution adsorption tests on silver bromide sols are in accordance with the photographic development results.

Photographic development is a complex sequence of chemical and physical processes. More particularly these processes can be considered as a heterogeneous catalytic reduction of silver ions by a suitable reducing agent. The chemical aspect of photographic development is the reduction of the silver halide to silver according to Eq. (1):

$$AgX + \text{red.} \rightarrow Ag + X^- + \text{ox} \qquad (1)$$

where: red. = the reducing agent
ox = the oxidation product of the reducing agent
X = halogen

Electrochemically, Eq. (1) may be considered to occur in two separate steps — an anode reaction (A) and a cathode reaction (B):[1]

$$\text{(A)}\ \text{red.} \rightarrow \text{ox} + \text{ne}$$
$$\text{(B)}\ AgX + e \rightarrow Ag + X^-$$

During the last years, several research workers have examined the different factors which determine the anode reaction (A) and the cathode reaction (B). Summarizing, the different processes of the anode reaction (A) may be described as follows:[2]

1. Supply of the developer (reducing agent) to the silver halide crystal surface
   a. diffusion phenomena in solution and in the colloid layers,
   b. the electrokinetic zeta-potential in the loosely bound interface between the nucleus and the solution,
   c. adsorption of the developer on the nucleus.
2. Transfer of an electron of the developer to the nucleus.
3. Diffusion of the oxidation products of the developer into the solution, affected by the desorption speed and the zeta-potential.

Received 8 October 1959.

1. W. Jaenicke and G. Schott, *Z. Elektrochem.*, **59:** 956 (1953).
2. J. Eggers, E. Klein, and R. Matejec, *Angew. Chem.*, **69:** 291 (1957).

According to experimental conditions, one or more of these partial processes can determine the rate of development.

According to Jaenicke,[3] the diffusion 1*a* is rate-determining in strongly alkaline hydroquinone solutions.

On the other hand, several investigators have already pointed out the importance of the effect of the electric double layer of the silver halide crystal on the rate of development. Whereas an ideal crystal of silver halide has no charge, the silver halide for practical purposes is mostly prepared in the presence of an excess of halide ions, producing a negative zeta-potential. The investigations of James and his coworkers[4] have shown that this negative potential barrier of the silver halide particles exerts a great influence on the kinetics of development. The greater the negative charge of the developer, the smaller is the probability of penetrating the negative potential barrier of the silver halide and the longer is the induction period of the development. The development rate by developers with a negative charge is appreciably accelerated when the negative charge of the potential barrier is lowered by adsorbed agents, such as positively charged dye ions, onium salts, etc.

Lu Valle and Jackson[5] have shown that the zeta-potential of a silver bromide sol of pAg 8, of an initial value of about −60 mv, at pH 9 is reduced to practically 0 mv by adsorption of lauryl pyridinium bromide.

The influence of the structure of quaternary ammonium compounds upon the acceleration of the development by negatively charged developing ions was studied by Willems,[6] who has shown that in the

3. W. Jaenicke, in *Wissenschaftliche Photographie* (Ergebnisse der Intern. Konfer. wiss. Phot., Köln, 1956), Verlag Dr. O. Helwich, Darmstadt, 1958, p. 386.
4. T. H. James, *J. Franklin Inst.*, **240:** 15, 83, 229, 327 (1945); T. H. James and G. Kornfeld, *Chem. Rev.*, **30:** 1 (1942).
5. J. E. Lu Valle and J. M. Jackson, *J. Phys. Chem.*, **61:** 1216 (1957).
6. J. Willems, in *Wissenschaftliche Photographie* (Ergebnisse der Intern. Konfer. wiss. Phot., Köln, 1956), Verlag Dr. O. Helwich, Darmstadt, 1958, p. 405; *Sci. et ind. phot.*, **27:** 487 (1956).

adsorption of quaternary ammonium compounds onto the silver halide surface not only electrostatic forces play a role, but also mutual association forces are of great importance in raising the potential barrier to more positive values.

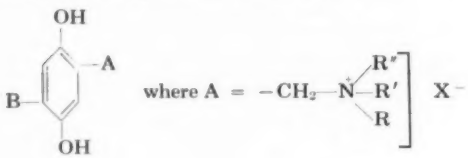
The object of this investigation is to determine to what extent the partial processes 1*b* and 1*c* of the anode reaction (A) may be influenced in photographic development by negatively charged developing ions wherein one or more positively charged groups were introduced by chemical modification.

Results and Discussion

Considering this problem more closely, we have studied developers of the hydroquinone type. It is known that a rather strong induction period is observed during development by hydroquinone, due to the singly and/or doubly negatively charged reducing ion:

The diffusion of those ions to the silver halide crystal surface is counteracted by an electrostatic repulsion, due to the negative potential barrier of the silver halide particles.

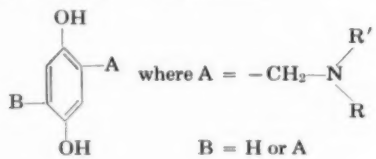
In order to cancel or at least to decrease this electrostatic repulsion, we have introduced positively charged substituents into the hydroquinone molecule and studied the photographic development by developers of the general formula (**I**):



(**I**)

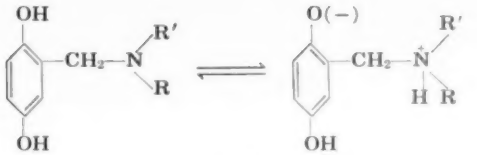
R, R′, and R″ are alkyl groups
X = a halide or an alkylsulfate ion
B = H or A

These derivatives may be prepared from the Mannich-reaction product (**II**) of hydroquinone, formaldehyde and an amine, by alkylation:

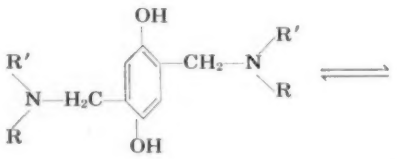


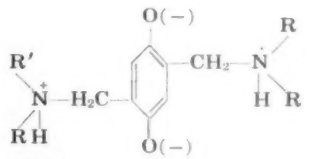
(**II**)

The mono- and bis-alkylaminomethyl hydroquinones (**II**) were likewise studied since these compounds can also be considered — although to a lesser extent — to bear one or two positively charged groups (Structures **IIIa** and **IIIb**).



(**IIIa**)





(**IIIb**)

A survey of the synthesized derivatives is shown in Table I.

Development tests with these compounds (Nos. 1 – 11, Table I) and with hydroquinone were carried out in developing baths, containing 0.0275 mole of developer, 25 grams of sodium sulfite, and 1 gram of potassium bromide per liter. The development was performed in a specially designed apparatus, in which the stirring speed, the temperature (20°C ± 0.01°C) and the pH (pH = 10) were kept constant. The photosensitive material to be developed was a Gevaert Positive fine-grain emulsion.

Figures 1(a), 2(a), 3(a), and 4(a) illustrate the relation between the development time and the resulting density of a well-defined step of the wedge through which the material was exposed. It appears quite clearly that the induction period of photographic development by hydroquinone compounds, bearing a positively charged group, is considerably shortened and that a particularly fast development is attained.

As expected, this effect is most pronounced with the quaternary salts, since the latter carry the strongest positive charges. However, shortening of the induction period in photographic development by nonquaternized dialkylaminomethyl hydroquinones is also apparent.

The introduction of a second positive center (Compounds 7 and 9) apparently exerts no further influence on the shortening of the induction period. The substitution of N-ω-hydroxy alkyl groups for the N-alkyl groups, whereby the positive charge upon the nitrogen atom is to some extent electrostatically screened off by the negative oxygen, has also an effect on the development. Indeed, Compounds 2 and 3 develop faster than Compounds 4 and 5. In this connection, it is noteworthy that compounds

Fig. 1a. (*Left*) Relation between density and time of development. A — 10 grams of Compound 3; B — 5.5 grams of Compound 2; C — 3 grams of hydroquinone. (See Table I for compounds referred to in this and other figures.)
Fig. 1b. (*Right*) Chromatographic displacement of Dye IV by: A — Compound 3; B — Compound 2; C — Hydroquinone.

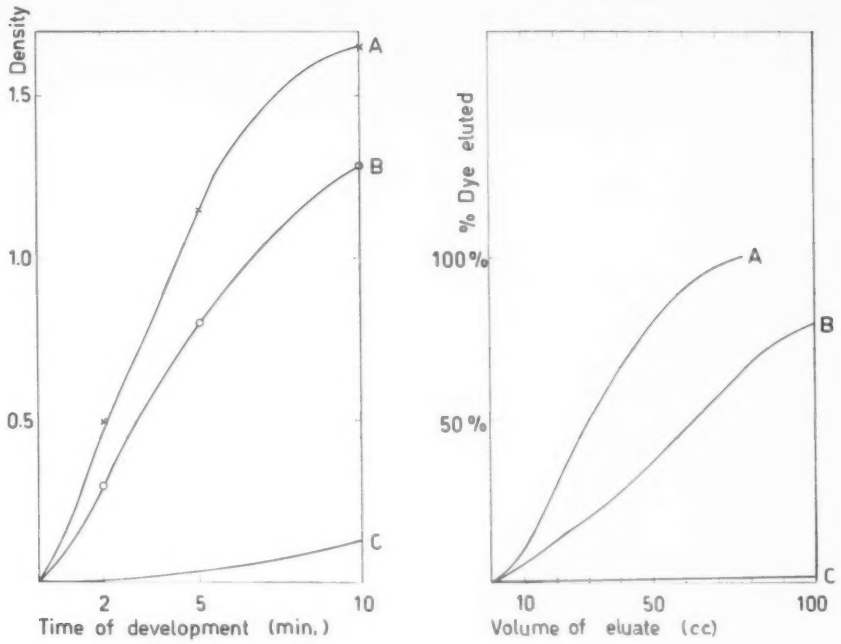
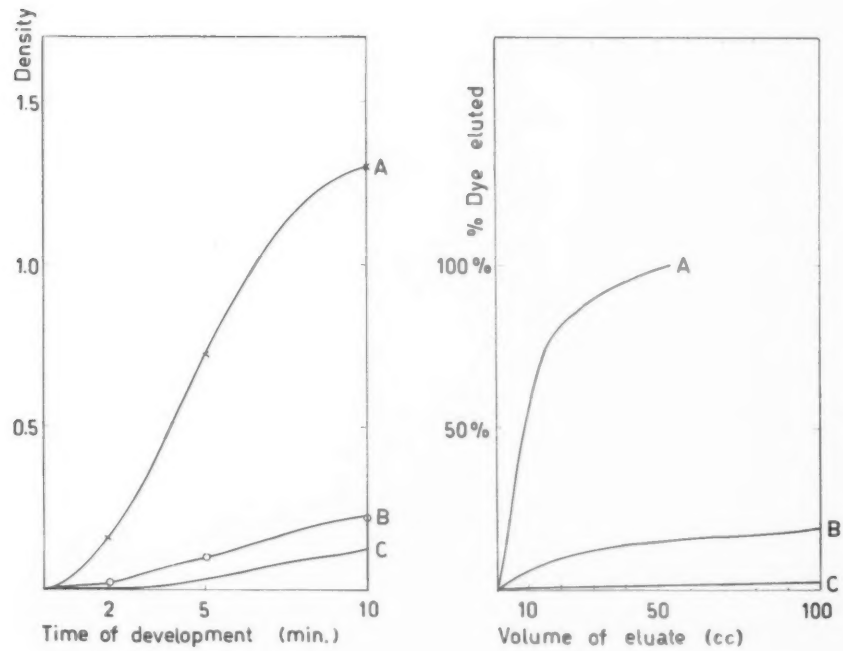
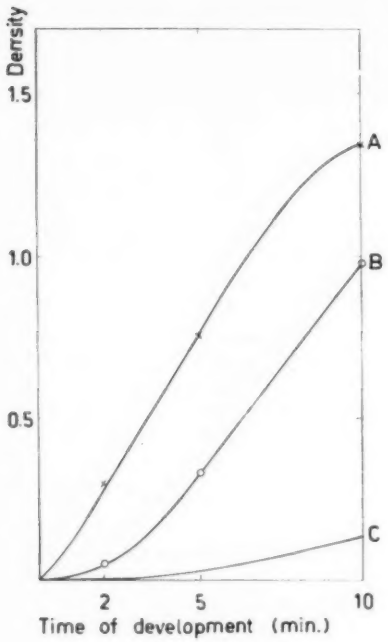


Fig. 2a. (*Left*) Relation between density and time of development. A — 10.4 grams of Compound 5; B — 6.2 grams of Compound 4; C — 3 grams of hydroquinone.
Fig. 2b. (*Right*) Chromatographic displacement of Dye IV by: A — Compound 5; B — Compound 4; C — Hydroquinone.





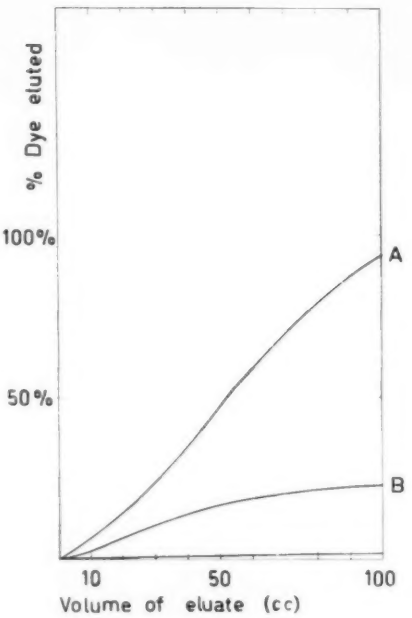
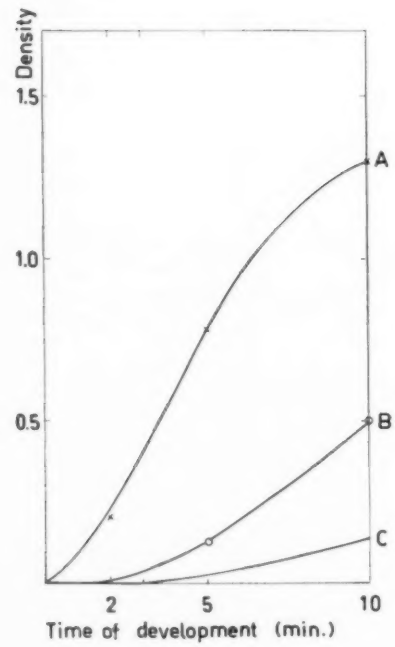


Fig. 3a. (*Left*) Relation between density and time of development. A — 13 grams of Compound 7; B — 6 grams of Compound 6; C — 3 grams of hydroquinone.
Fig. 3b. (*Right*) Chromatographic displacement of Dye IV by: A — Compound 7; B — Compound 6; C — Hydroquinone.



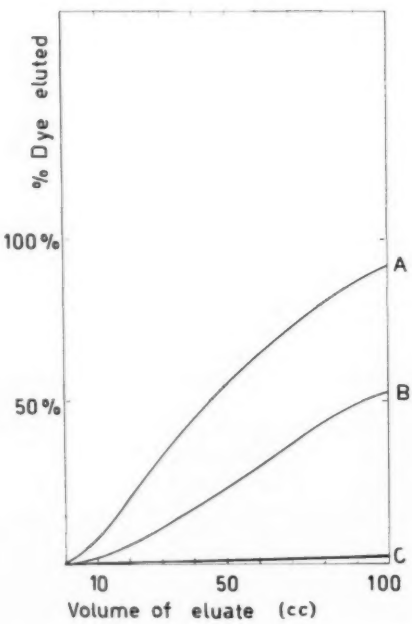


Fig. 4a. (*Left*) Relation between density and time of development. A — 20 grams of Compound 9; B — 12 grams of Compound 8; C — 3 grams of hydroquinone.
Fig. 4b. (*Right*) Chromatographic displacement of Dye IV by: A — Compound 9; B — Compound 8; C — Hydroquinone.

Fig. 5a. (*Left*) Relation between density and time of development. A — 19 grams of Compound 10; B — 15 grams of Compound 11; C — 3 grams of hydroquinone.
Fig. 5b. (*Right*) Chromatographic displacement of Dye IV by: A — Compound 10; B — Compound 11; C — Hydroquinone.

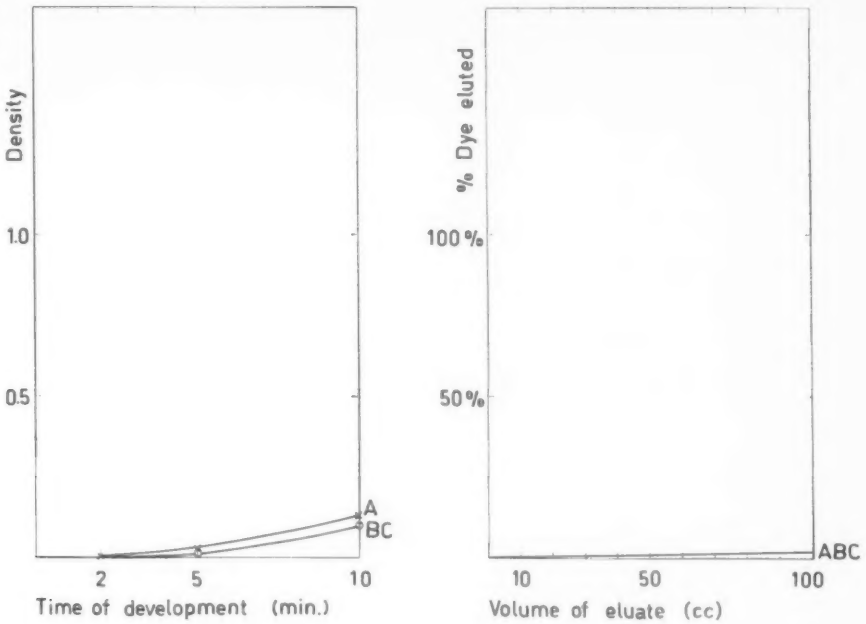


Fig. 6. (*Left*) Relation between density and time of development. A — 10 grams of Compound 3; B — 5 grams of *p*-methylaminophenol hemisulfate; C — 3 grams of hydroquinone and 0.6 grams of 2-methyl benzimidazole pyridinium chloride; D — 3 grams of hydroquinone.

Fig. 7. (*Right*) Relation between density and time of development. A — × = 10 grams of Compound 3, 0 = 10 grams of Compound 3 plus 3 grams of hydroquinone; B — × = 3 grams of Compound 3, 0 = 3 grams of Compound 3 plus 3 grams of hydroquinone; C_1 — × = 0.5 grams of Compound 3, 0 = 0.5 grams of Compound 3 plus 3 grams of hydroquinone.

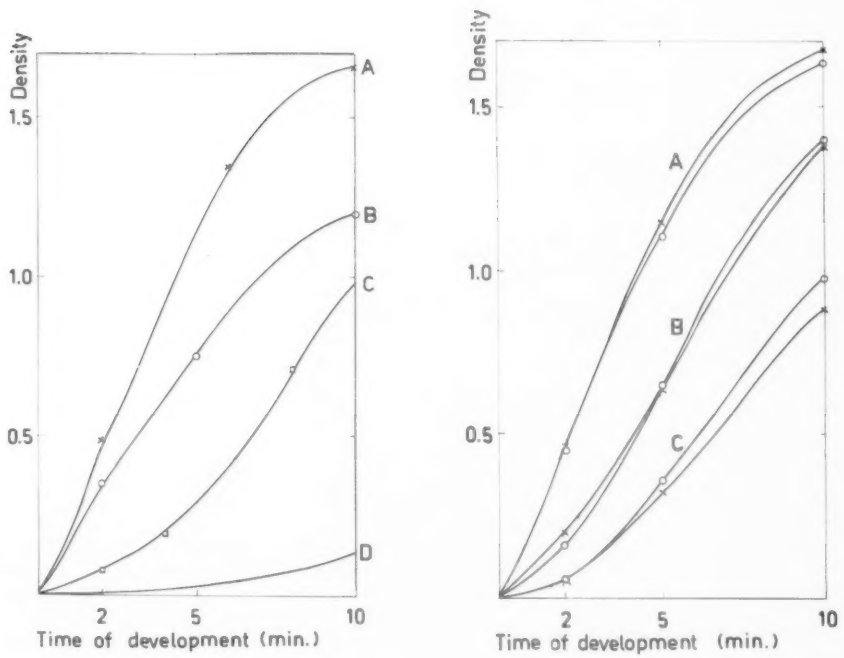


TABLE I

No. of Compound	A	B	Half-wave potential, mv at pH 8	Half-wave potential, mv at pH 10	Adsorption by 1 gram AgBr $\times 10^{-3}$ mmoles
1	H	H	−56	−174	——
2	$-H_2C-N(C_2H_5)(C_2H_5)$	H	−34	−165	——
3	$-H_2C-N^+(C_2H_5)(C_2H_5)(C_2H_5)\ C_2H_5SO_4^-$	H	−6	−135	0.62
4	$-H_2C-N(C_2H_4OH)(C_2H_4OH)$	H	−33	−157	——
5	$-H_2C-N^+(C_2H_4OH)(C_2H_4OH)(C_2H_5)\ C_2H_5SO_4^-$	H	−28	−150	0.78
6	$-H_2C-N(CH_3)(CH_3)$	$-H_2C-N(CH_3)(CH_3)$	+9		——
7	$-H_2C-N^+(CH_3)(CH_3)(CH_3)\ CH_3SO_4^-$	$-H_2C-N^+(CH_3)(CH_3)(CH_3)\ CH_3SO_4^-$	+58	−45	0.53
8	$-H_2C-N(C_2H_4OH)(C_2H_4OH)$	$-H_2C-N(C_2H_4OH)(C_2H_4OH)$	−20	−153	——
9	$-H_2C-N^+(C_2H_4OH)(C_2H_4OH)(C_2H_5)\ C_2H_5SO_4^-$	$-H_2C-N^+(C_2H_4OH)(C_2H_4OH)(C_2H_5)\ C_2H_5SO_4^-$	−26	−156	0.72
10	$-H_2C-N^+(C_2H_5)(C_2H_5)(CH_2-C_6H_4-SO_3H)\ Cl^-$	$-H_2C-N^+(C_2H_5)(C_2H_5)(CH_2-C_6H_4-SO_3H)\ Cl^-$	+19	−125	——
11	$-H_2C-N^+(C_2H_5)(C_2H_5)(CH_2)_4-SO_3^-$	$-H_2C-N^+(C_2H_5)(C_2H_5)(CH_2)_4-SO_3^-$	+19	−122	——

with hydroxyalkyl substitution nevertheless show a more negative half-wave potential (see Table I).

The same effect is observed for Compounds 6 and 7 vs. Compounds 8 and 9, although in that case a methyl substitution is compared to an hydroxyethyl substitution.

We have also investigated to what extent the shortening of the induction period of development by hydroquinone compounds with a positively charged group is comparable to the shortening of the induction period in development by an equivalent quantity of hydroquinone in the presence of a quaternary ammonium salt (Fig. 6, Curves A, C, and D). The resulting effects are considerably larger for the de-

velopers with a positively charged group than for the corresponding mixture of hydroquinone and quaternary ammonium development accelerator.

In the same figure, the development curve (Fig. 6, Curve B) obtained under the identical experimental conditions with *p*-methylaminophenol hemisulfate is shown. Hydroquinone derivatives with a quaternary nitrogen atom develop at least equally fast in the examined circumstances.

The supposition that the disappearance of the induction period in photographic development by the investigated compounds can only be due to the introduction of a positively charged group in the hydroquinone molecule is supported by the results obtained with hydroquinone derivatives in which these positive charges have been compensated by substitutions of alkyl groups containing a very strong negative group (Compounds 10 and 11). The introduction of sulfonic acid groups masks the positive charge upon the quaternary nitrogen atom and these compounds again possess the properties of hydroquinone itself and show the same great induction period (Fig. 5a).

In order to ascertain that the shortening of the induction period during development with the investigated hydroquinone compounds is only due to influencing the partial processes 1*b* and 1*c*, and not to the partial process 2 of the anode reaction (A), we have determined to what extent the introduction of the dialkylaminomethyl groups and of the trialkylammoniummethyl groups into the hydroquinone molecule affects the reducing power of these developers.

Assuming that all processes are reversible, Eq. (2) is applicable for the partial process 2 of the anode reaction (A) and Eq. (3) for the cathode reaction (B), according to the theory of Nernst.

$$E_{\text{red.}} = E_{0\,\text{red.}} + \frac{RT}{nF} \log \frac{C_{\text{ox}}}{C_{\text{red.}}} \qquad (2)$$

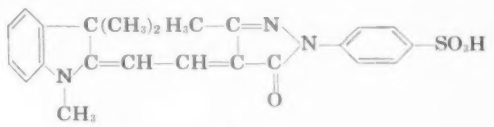
$$E_{\text{Ag}} = E_{0\,\text{Ag}} + \frac{RT}{F} \log \frac{C_{\text{Ag}^+}}{C_{\text{Ag}}} \qquad (3)$$

Although it is not our purpose to discuss here more in detail the controversial existence of a possible relation between $\Delta E_0 = E_{0\,\text{Ag}} - E_{0\,\text{red.}}$ and the development rate of the investigated developers of the hydroquinone type with positively charged groups, nevertheless, the value $E_{0\,\text{red.}}$ — in view of the chosen experimental conditions we suppose the cathode reaction (B) to be always the same — or the half-wave potential $E_{\frac{1}{2}}$ represents a measure of the thermodynamic possibility of the reduction process. The values of the half-wave potentials of the investigated developers for two different pH's (in buffer mixtures pH 8 and pH 10) are tabulated in the fourth column of Table I.

The electron-releasing properties of the methyl group in position 2 of the hydroquinone molecule are strongly reduced, both by the dialkyl amino substitution and *a fortiori* by the ammonium substitution, and the half-wave potentials are shifted to more positive values. The hydroquinone derivatives with positively charged groups possess a smaller reducing power than hydroquinone.

It may be concluded, therefore, that the introduction of the positive groups into a negatively charged hydroquinone molecule results only in a diminution of the electrostatic repulsion of these compounds by the negative potential barrier and in a more easy adsorption at the silver halide surface; hence the disappearance or the shortening of the induction period.

A confirmation of this explanation was found in the elution-chromatographic tests with these compounds, using negatively charged silver halide sols. Whereas hydroquinone cannot displace the previously adsorbed dye, 1-(4-sulfophenyl)-3-methyl-4-[1′,3′,3′-trimethyl-2-(2′-indolylidene)ethylidene]-5-pyrazolone (**IV**):



(**IV**)

from the silver halide surface, the ammonium substituted hydroquinones and, to a smaller extent, the nonquaternized dialkylaminomethyl hydroquinones (Figs. 1b, 2b, 3b, and 4b) displace the dye.

Experiments, in which the amount of adsorbed developer has been determined by an analytical procedure, provide absolute evidence for the adsorption of the trialkylammonium-methyl hydroquinones by negatively charged silver bromide sols. The values found are shown in the fifth column, Table I. These values are, within the limits of error of the experimental techniques, well in accordance with the value 0.5×10^{-3} mmole/gram AgBr sol, given by James and Vanselow[7] for the adsorption of 3,3′-diethyl-9-methylthiacarbocyanine chloride by the silver bromide sol used in our adsorption elution tests (see experimental part). The adsorption of the nonquaternized dialkylaminomethyl hydroquinones is probably too small to be detectable by this method.

In comparison with the quaternary ammonium salts, previously investigated by us,[6] the strength of adsorption of the trialkylammoniummethyl hydroquinone by the silver bromide sols is much weaker. These compounds do not displace more strongly adsorbed dyes, such as malachite green and phenosafranine, from the silver bromide surface. They cannot be considered as accelerating agents of photographic development by negatively charged developers in the same sense as the quaternary ammonium compounds of our previous study,[6] and they do not accelerate development by hydroquinone. The development obtained by addition of, e.g., Compound 3 to a hydroquinone-containing developing composition is the same as that obtained without hydroquinone (Fig. 7).

7. T. H. James and W. Vanselow, *J. Am. Chem. Soc.*, **73**: 5617 (1951).

The possible accelerating action of 1-phenyl-3-pyrazolidone (Phenidone) on the development by the hydroquinone compounds with positively charged groups has also been studied at different pH's. Figure 8 illustrates the lack (compare Curve C with Curve A) of the strong superadditivity found with the classical mixture hydroquinone-Phenidone (Curves D and B). Only below pH 11.5 is a noticeable increase of the development observed. However, more detailed experiments on the behaviour of these mixtures are in progress.

The present data again indicate that the influence of the chemical structure of the developer is not only of importance for the partial reaction 2 of the anode process (A) — since the chemical structure defines the $E_{0\,red.}$ in Eq. (2) — but that the chemical structure is likewise of essential importance for overcoming the negative potential barrier of the silver halide and for the adsorption at the silver halide crystal (partial processes 1*b* and 1*c*) and consequently influences the rate of photographic development.

Experimental Procedure

A. Synthesis of the developers

1. The mono- and bis-alkylaminomethyl hydroquinones. The following general procedure was followed: 1 mole of hydroquinone was suspended in 250 cc of water below 10°C under an atmosphere of nitrogen and 1 mole of the appropriate amine was added (or 2 moles for the preparation of the bis-compound). Next, 1 mole (or 2 moles for the bis-compound) of formaldehyde was added dropwise as a 40% formaldehyde solution. The dialkylaminomethyl hydroquinone was separated and crystallized. The following were prepared by this method:

a. 2-[N,N-bis(β-hydroxyethyl)aminomethyl]hydroquinone (Compound 4) (cf. Ref. 8). Melting point: 149–150°C* (acetone). *Analysis:* N % calcd. 6.16; found 6.05 – 6.03. Molecular weight: calcd. 227; found (by redox titration with ceric sulfate) 227.

b. 2,5-Bis(N,N-diethylaminomethyl)hydroquinone. Melting point: 107°C (acetone). *Analysis:* N % calcd. 10.0; found 9.96 – 10.14. Molecular weight: calcd. 280; found (by redox titration with ceric sulfate) 280 – 276.

c. 2,5-Bis(N,N-dimethylaminomethyl)hydroquinone (Compound 6). Melting point: 190°C (acetone). *Analysis:* N % calcd. 12.50; found 12.61 – 12.77. Molecular weight: calcd. 224; found (by redox titration with ceric sulfate) 227 – 226.

d. 2,5-Bis [N,N-di(β-hydroxyethyl)aminomethyl] hydroquinone oxalate (Compound 8). Melting point: 222°C. *Analysis:* N % calcd. 6.45; found 6.42 – 6.39. Molecular weight: calcd. 434; found by (1) redox titration with ceric sulfate, 434 – 434, (2) acid-base titration with sodium hydroxide, 429 – 431.

e. 2-(N,N-diethylaminomethyl)hydroquinone (Compound 2). The mono-compound cannot be prepared according to this working method as we always obtained mixtures of products which could not be separated. We succeeded, however, in the synthesis by starting from the monomethylether of hydroquinone. The mono-Mannich reaction product was demethylated afterwards.

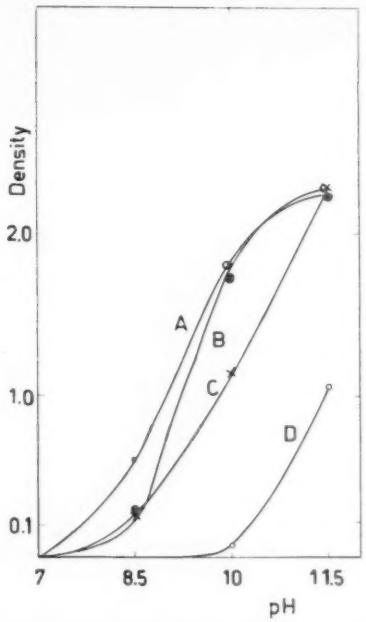


Fig. 8. Relation between density and pH (time of development — 5 min). A — 10 grams of Compound 3 and 0.050 grams of 1-phenyl-3-pyrazolidone; B — 3 grams of hydroquinone and 0.050 grams of 1-phenyl-3-pyrazolidone; C — 10 grams of Compound 3; D — 3 grams of hydroquinone.

i. 248 grams of monomethylether of hydroquinone was suspended in 500 cc of water. 146 grams of diethylamine was added dropwise at 10°C and under an atmosphere of nitrogen. Then 172 cc of formaldehyde 35% was added between 0°C and 5°C. The brown oil formed was separated and washed thrice with water. This oil was dissolved in ether and dried over anhydrous sodium sulfate. A stream of dry hydrogen chloride was passed through the solution and the hydrochloride crystallized. Melting point: 132°C.

ii. 100 grams of the hydrochloride were dissolved in 750 cc of 47% of hydrogen bromide and this mixture was boiled for 6 hours. The solution was concentrated under reduced pressure and the residue was triturated with acetone. The 2-(N,N-diethylaminomethyl)hydroquinone hydrobromide was recrystallized from a mixture of acetonitrile and ether. Melting point: 130°C. *Analysis:* N % calcd. 5.08; found 5.06 – 5.17. Br % calcd. 28.95; found 28.97 – 29.12.

The free base was obtained by dissolving the hydrobromide in water and neutralizing with sodium bicarbonate. The free base was extracted with ether. After concentrating the ether, the 2-(N,N-diethylaminomethyl)hydroquinone crystallized in white crystals. Melting point: 113°C. *Analysis:* C % calcd. 67.75; found 67.71. H % calcd. 8.79; found 8.91. N % calcd. 7.18; found 6.98 – 6.97. Molecular weight: calcd. 195; found (by redox titration with ceric sulfate) 196 – 197.

2. The mono- and bis-trialkylammoniummethyl hydroquinones. These compounds can be prepared in a very simple way by alkylating the corresponding amines

* The melting points are taken on the Kofler-melting bar.

8. C. Weatherbee, R. Temple, and W. J. Burke, *J. Org. Chem.*, **21**: 1138 (1956).

with dialkylsulfates in acetone. Several of these quaternary compounds could not be obtained in the crystalline state. They were thoroughly purified by chromatography upon aluminium oxide and silica gel.

a. 2-(Triethylammoniummethyl)hydroquinone ethyl sulfate (Compound 3). Viscous oil. *Analysis:* S % calcd. 9.16; found 9.42 – 9.43. Molecular weight: calcd. 349; found (by redox titration with ceric sulfate) 353 – 355.

b. 2 - [Di(β - hydroxyethyl)ethylammoniummethyl]-hydroquinone ethyl sulfate (Compound 5). Viscous oil. *Analysis:* S % calcd. 8.39; found 8.2 – 8.09. N % calcd. 3.67; found 3.69 – 3.70. Molecular weight: calcd. 381; found (redox titration with ceric sulfate) 384 – 384.

c. 2,5 - Bis(trimethylammoniummethyl)hydroquinone dimethyl sulfate (Compound 7). Melting point: 216°C (ethanol). *Analysis:* S % calcd. 13.44; found 12.97 – 12.75. N % calcd. 5.89; found 5.67 – 5.77. Molecular weight: calcd. 476; found (redox titration with ceric sulfate) 479 – 476.

d. 2,5- Bis [di(β - hydroxyethyl)ethylammoniummethyl]hydroquinone diethyl sulfate (Compound 9). Viscous oil. *Analysis:* S % calcd. 9.82; found 9.58 – 9.57. N % calcd. 4.28; found 4.22 – 4.19. Molecular weight: calcd. 652; found (redox titration with ceric sulfate) 659 – 661.

According to a somewhat adapted procedure the following were prepared:

e. 2,5 - Bis(4 - sulfobenzyldiethylammoniummethyl)-hydroquinone dichloride (Compound 10). 1 mole of amine was alkylated for 10 hours with 2 moles of *p*-sulfobenzyl chloride under pressure at 120°C. The residue was recrystallized from a mixture of ethanol and dioxane (1:1). *Analysis*: Cl % calcd. 10.84; found 9.96–9.75. S % calcd. 9.25; found 9.20–9.36. Molecular weight: calcd. 693; found (redox titration with ceric sulfate) 692–693.

f. 2,5 - Bis(4 - sulfobutyldiethylammoniummethyl)hydroquinone (Compound 11). 7 grams of amine and 6.8 grams of 4-hydroxy-1-butanesulfonic acid sultone were heated during 6 hours at 100°C. The resinous residue was triturated with acetone, and the powder obtained was dissolved in ethanol. The compound was crystallized by addition of ether. *Analysis:* S % calcd. 11.60; found 11.63 – 11.56. Molecular weight: calcd. 552; found (by redox titration with ceric sulfate) 558 – 556.

B. Development tests

The development tests were carried out in a specially designed thermostated apparatus (20°C ± 0.01°C) with constant stirring speed. The developing bath contained an amount of developing agent equivalent to 3 grams of hydroquinone and had the further composition:

Developer	*x* grams
Na_2SO_3 anhydrous	25 grams
Na_2CO_3 anhydrous	10 grams
KBr	1 gram
Water to make	1 liter

The pH was always adjusted to pH 10.

The sensitive material was a Gevaert Positive fine-grain film exposed for a fixed time behind a sensitometric step wedge. The densities obtained were measured with an Ansco densitometer and the density of a determined step of the wedge was plotted as a function of the development time.

C. Adsorption tests

The elution was carried out on a column (diameter 0.6 cm, length 25 cm) charged with 9 grams of a specially prepared negatively charged silver bromide sol.[7] Dye from 1 cc $N/1000$ solution of **IV** was adsorbed on the silver bromide. The displacement of this dye then was executed with an aqueous solution ($N/5$ or $N/25$) of the investigated developers at a constant pH of 5.2 and the elution was carried out under a constant pressure of nitrogen of 1.5 kg/sq cm. The density of the eluted dye (λ max: 476 mμ) was spectrophotometrically determined on a Unicam spectrophotometer. The amount of eluted dye is plotted as a function of the number of cubic centimeters of eluate.

For the absolute determinations, the same sol was used without adsorbed dye, and the amount of developer was analytically determined before and after adsorption.

D. Polarographic half-wave potential determinations

These determinations were executed in two different buffer mixtures (pH 8 disodium hydrogen phosphate – citric acid; pH 10, sodium carbonate – sodium bicarbonate) in a 10% ethanol solution. The concentration of the developing substance in all cases was 0.001*M*. A recording polarograph, the Radiometer PO-3, was used. The potential was controlled with a potentiometer "Pye." A saturated calomel cell was used as an external reference electrode. The resistance of the cell was measured with a Wheatstone bridge and a correction was made for the I.R.-drops in the cell. The solutions were brought to 25°C ± 1% in a thermostat and purged with a slow stream of oxygen-free, solvent-saturated nitrogen, immediately before the measurements.

Acknowledgments

I should like to thank Prof. Dr. A. Van Dormael, Director, Chemical Research Department, Gevaert Photo-Producten N.V., for his kind interest in this study. The polarographic half-wave potential determinations described immediately above were performed by our colleague, Dr. R. Janssen, to whom I am greatly indebted.

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The Stability of Concentrated Ammonium Thiosulfate Solutions at High Temperature

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Sodium and ammonium thiosulfate liquors were stored in sealed glass tubes at 60°C. The effect of pH value, sulfite concentration, dilution, etc., on the time required to bring about deposition of sulfur from the solution was observed. The stability was not primarily dependent on whether sodium or ammonium salts were used. The stability rapidly decreased as the pH value and sulfite concentration were lowered. Sulfite reacted with the thiosulfate and when all the sulfite was consumed the thiosulfate decomposed.

Concentrated liquid fixers are based on an ammonium thiosulfate liquor containing about 60% w/v $(NH_4)_2S_2O_3$. The solutions contain sulfurous acid equivalent to about 3% w/v $(NH_4)_2SO_3 \cdot H_2O$. The concentrates may also contain components such as boric and acetic acids. Such concentrated liquid fixers are usually free from hardening compounds; they are mixed with an aluminum-containing auxiliary when the working-strength fixer is made up. The hardening, auxiliary solution is of no further interest in this paper, which is concerned solely with the stability of the concentrated fixer component.

If a concentrated acid solution of thiosulfate of this sort is stored under tropical conditions, it will, after some weeks, suddenly decompose. For example, a concentrated fixer was stored in a sealed tube at 49°C (120°F) and decomposed on the thirteenth day. The appearance of the decomposition was most remarkable. A tube of clear solution that had stood nearly two weeks without noticeable change became cloudy in a band near the surface. Within minutes, the cloudiness spread downwards through the tube. Thereafter, the precipitation continued until, after one day, there was a considerable bulk of crystalline sulfur in the bottom of the tube, underneath a clear liquor.

This phenomenon was observed under various conditions in a qualitative way and then the following series of tests were made as a more systematic preliminary investigation to disclose the factors governing the remarkably sharp way in which these concentrated liquors decompose.

Experimental Procedure

A typical commercial ammonium fixing concentrate, Fixer A, was used for some of the tests. The pH was adjusted where necessary by adding either ammonia or acetic acid. Reagent-grade ammonium thiosulfate (solid) was twice washed with carbon disulfide to remove sulfur and eliminate a smell of sulfide. The desiccated residue was found to correspond to 99.9% $(NH_4)_2S_2O_3$. Ammonium sulfite was prepared in solution form from bottled sulfur dioxide and strong aqueous ammonia, which gave a liquor corresponding to 32% w/v $(NH_4)_2SO_3 \cdot H_2O$.

All the pH determinations quoted here are the values as determined by a glass electrode at room temperature. All incubations were carried out at 60°C (140°F).

Thiosulfate and sulfite were determined iodimetrically, formaldehyde being used to sequester the sulfite in order to obtain the thiosulfate titer.

Results

Figure 1 shows the combined results from three runs in which lots of 25 ml of Fixer A were adjusted to various pH levels with ammonia or acetic acid, and the total volume was made up in each case to 27 ml. The samples were sealed in glass tubes. At pH levels from about 5.2 downwards, the liquors were increasingly lemon-yellow in tint. Shortly before the time of decomposition, the yellow tint faded and decomposition set in within a few minutes of the total disappearance of the color.

The samples above pH 5.5 were substantially colorless and there was no warning of the onset of decomposition.

The data, plotted as log time vs. pH, form a curve that seems to have a comparatively low slope in the pH range, 5.0 – 5.8.

Although the onset of decomposition was very sharp, the sulfur continued to precipitate for several days. Figure 2 shows a set of results obtained by the incubation of a number of identical tubes of a mixed solution of ammonium thiosulfate (567 grams/liter) and ammonium sulfite (29.5 grams/liter). The pH was adjusted, by additions of acetic acid, to 4.2, at which level the solutions decomposed rapidly.

Presented at the National Conference, Chicago, 30 October 1959. Communication No. 2053H, from the Kodak Research Laboratories, received 17 December 1959.

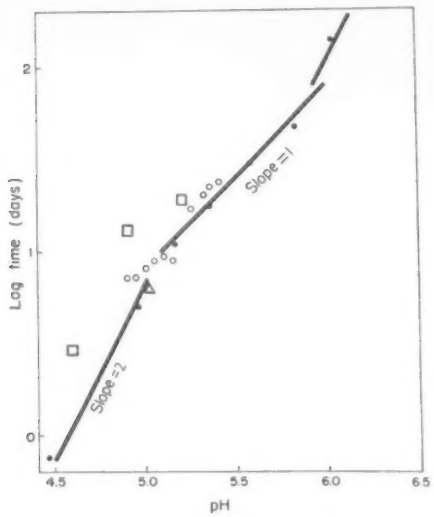


Fig. 1. Effect of pH on stability of Fixer A at 60°C. Three runs with Fixer A ●, O, and △. Sodium thiosulfate solutions equivalent to Fixer A, □.

Incubation continued for several days, a tube being opened for analysis from time to time. The precipitation of sulfur was not fully completed in eight days. Figure 2 shows that the quantity of precipitated sulfur corresponded reasonably well with the loss in thiosulfate. No sulfite was found in the tubes, in which decomposition had occurred.

The role of sulfite in the process was investigated by means of another series of tubes containing an ammonium thiosulfate – sulfite solution which was incubated and analyzed in rapid succession to reveal any changes preceding decomposition. The results, seen in Fig. 3, show that there was an accelerated fall in sulfite concentration, and decomposition set in within a few minutes of the complete disappearance of the sulfite. Up to this point there was no significant change in the thiosulfate content.

Further experiments were made to follow the pH changes, as measured on the cooled samples, during the incubation of two ammonium thiosulfate (600 grams/liter) solutions with 30 and 50 grams/liter

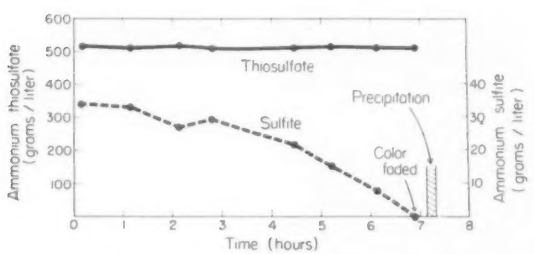


Fig. 3. Incubation of ammonium thiosulfate – sulfite solution at 60°C and at initial pH 4.19.

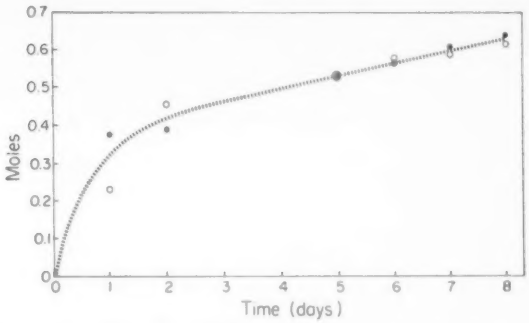


Fig. 2. Equivalence between thiosulfate decomposed and sulfur precipitated at initial pH 4.2; thiosulfate decomposed — ●, sulfur precipitated — O.

additions of ammonium sulfite, respectively. The solutions were adjusted with acetic acid to pH 4.1, though the first measurement at the start of incubation showed a rise in pH to 4.3 (Fig. 4). After this, the pH fell steadily until the decomposition point was reached; it then rose sharply and continued to rise while sulfur was being precipitated.

Figure 5 shows the relationship between the time required to reach decomposition and the initial concentration of sulfite for an ammonium thiosulfate (60%) plus ammonium sulfite series, pH 5.2, incubated at 60°C. In some cases the decomposition occurred unobserved and the graph shows the known times between which the solutions decomposed. Plotting the logarithm of the time against the logarithm of the concentration does not give a straight line, but most of the data are in accordance with the relations,

$$t = 12 \log_{10}(C/5)$$

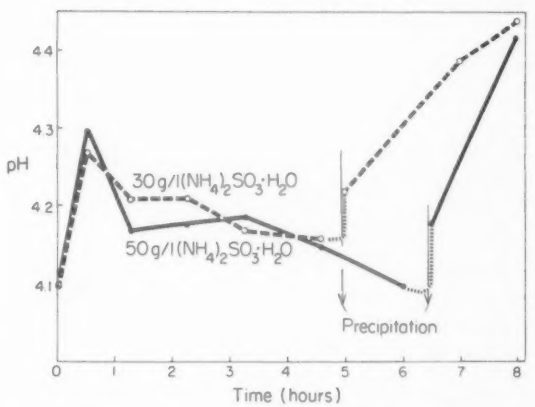


Fig. 4. Effect of incubation at 60°C on the pH of ammonium thiosulfate – sulfite solutions. Ammonium thiosulfate 600 grams/liter, ammonium sulfite at 50 grams/liter — solid curve; at 30 grams/liter — dashed curve.

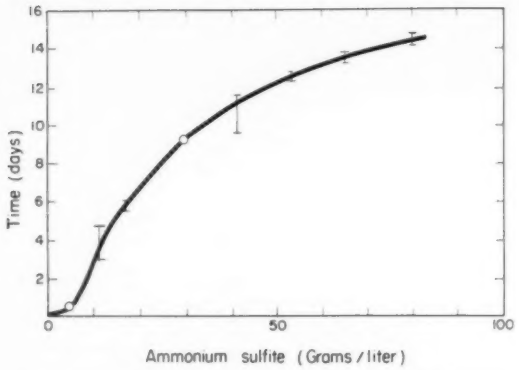


Fig. 5. Effect of sulfite concentration on the stability of ammonium thiosulfate (600 grams/liter) at 60°C and initial pH 5.2.

where t is the time in days, and C is the concentration in grams per liter.

The effect of dilution was examined using Fixer A at three levels of pH. The pH values of the concentrated and diluted samples were brought to the same level, though some error is likely to have occurred in the matching on account of the syrupy nature of the concentrate. The results are shown in Fig. 6. In all cases, the stability increased when the concentrate was diluted.

Vittum and Crabtree[1] reported that the Kodak Fixer F5 based on ammonium thiosulfate was at least as stable as the standard sodium thiosulfate form, provided the solutions were stored in sealed containers. This was checked at 60°C, using a sodium thiosulfate – bisulfite solution approximately equivalent to Fixer A, viz., about 1000 grams sodium thiosulfate ($5H_2O$) and 28 grams sodium sulfite per liter. The pH's were adjusted with acetic acid at about 40°C in the near-crystallizing liquor and should not be taken as very accurate. The results are shown on Fig. 1 and, although the times of stability shown are double those for the ammonium solutions, this is sufficiently close, under the circumstances, substantially to confirm the finding of Vittum and Crabtree.

Finally, an experiment was carried out to find whether the loss of sulfite was in any measure spontaneous. A solution of analytical-grade sodium sulfite, at 28 grams/liter, adjusted with acetic acid to pH 4.44, was sealed in tubes and incubated. Tubes were opened at intervals for analysis. In a run of 11 days, there was no apparent drop in sulfite concentration nor did any thiosulfate concentration appear. Another run was carried out using a near-saturated sodium sulfite – SO_2 – acetic acid liquor equivalent to an 87% w/v solution of anhydrous sodium sulfite. Again there was no drop in sulfite concentration nor appearance of thiosulfate during this run, which lasted 40 days.

1. P. W. Vittum and J. I. Crabtree, private communication.

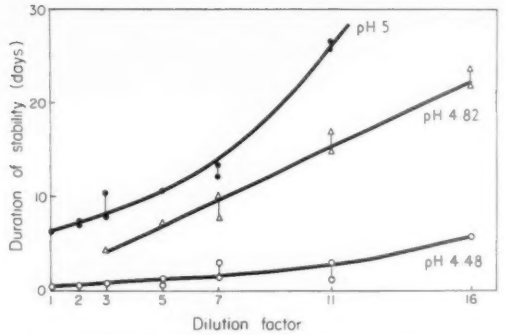


Fig. 6. Effect of dilution of stability of Fixer A at 60°C. and at pH 5 — ●; pH 4.8 — △; at pH 4.5 — O.

Discussion

Perhaps the first point to note in a discussion of these results is that ammonium thiosulfate concentrates are not specially worse than sodium thiosulfate concentrates in respect of stability if the storage is in sealed vessels. The most important factor influencing the life of a concentrated thiosulfate fixer is the pH value, and after this comes the initial sulfite concentration.

This preliminary study of the stability of thiosulfate solutions provides a fairly clear picture of the practical situation. On the chemical side, the present results suggest strongly that the "timing" mechanism maintaining apparent stability until the very sudden decomposition is the run-down in sulfite concentration. The sulfite is not independently decomposed because sulfite – acetic acid solutions at pH 4.96 are quite stable at 60°C. It appears that the thiosulfate acts almost as a catalyst in the decomposition of the sulfite, though the exact chain of reactions leading to the transformation of sulfite cannot be stated on the evidence of these preliminary experiments.

An interesting difference emerges between the present results for thiosulfate – sulfite – weak acid and those of workers like Gruenthal[2] who have studied the reactions in the simple case of thiosulfate – strong acid. That is, in the present work the sulfite is completely eliminated from the system whereas sulfite is an end product of the normal thiosulfate – strong acid reaction. In Gruenthal's work, for example, the sulfurous acid was present at substantially constant concentration from the second day to the sixth month of a run at 22°C.

The suddenness of the appearance of the decomposition in the incubated fixers follows from the acceleration in the loss of sulfite, which acceleration is probably caused simply by the attendant fall in pH value. To this must be added the probable need for the sulfur to reach a degree of supersaturation before it precipitates.

2 E. Gruenthal, summarized in *J. Phot. Soc. Am.* (*Phot. Sci. & Tech.*), **17B:** 90 (1951).

PHOTOGRAPHIC SCIENCE AND ENGINEERING
Volume 4, Number 2, March-April 1960

Color Balance and Camera Lens Color

F. C. WILLIAMS AND F. GRUM, *Research Laboratories, Eastman Kodak Company, Rochester, N.Y.*

Camera lenses transmit radiant energy of different wavelengths selectively. Lenses differ particularly in their transmission of ultraviolet energy, and these differences affect the color balance of color transparencies made by photography with the lenses. By means of photicity integrals, the nature and amount of this effect has been estimated for each of 79 different camera lenses of motion-picture, roll-, miniature-, and sheet-film camera types. The distribution of resulting effects is shown graphically.

The blue-sensitive layers of color films are sensitive to ultraviolet energy as well as to visible blue light. Ultraviolet energy can account for about one-third the exposure of the blue-sensitive layer of an ordinary color film in the image of a matte white object in daylight, if the camera lens freely transmits all energy of wavelengths longer than about 330 mμ.

Some camera lenses do transmit ultraviolet energy quite freely, but others transmit it far less freely than they do visible light. As a result, the exposure of the blue-sensitive layer of color films, relative to exposure of the green- and red-sensitive layers, differs from camera to camera. The color balance of color transparencies accordingly varies along a blue-yellow direction. Generally, color differences among production units of a given lens are small but color differences among various kinds of lenses may be disturbing and even intolerable.

This paper reports a study of 79 dissimilar camera lenses, to determine in what way and to what extent their selective transmissions affect the color balance of color transparencies made by photography with them. Some were new; some were old. Some were coated; some were not. They were of domestic, European, and Japanese manufacture, and from motion-picture, roll-, miniature-, and sheet-film cameras. They varied widely in their color-balance effects.

A few of the lenses were compared by actual photography of scenes and white cards in natural daylight. Quantitative estimates of differences were derived by comparing, sensitometrically, the white-card images and appropriate gray scales. But this means is too cumbersome and not sufficiently precise for intercomparisons of a large group. Instead, the lenses were evaluated by computing their actinic transmittances, defined by:

$$T = \frac{\int_0^\infty J_\lambda S_\lambda \tau_\lambda d\lambda}{\int_0^\infty J_\lambda S_\lambda d\lambda}$$

where J_λ is spectral radiant intensity of the (daylight) source, S_λ is spectral sensitivity of the pertinent emulsion, and τ_λ is transmittance at wavelength λ of the lens being evaluated. If either J_λ or S_λ is scaled to make the denominator unity, the numerator gives directly the actinic transmittance.

In the present work, the numerator integral was approximated by summing the products $J_\lambda S_\lambda \tau_\lambda$, taken at discrete values of λ in the series 330, 340, 350 . . . 660 mμ. The lower limit of λ was imposed by the shortest wavelength for which τ_λ exceeds 1%. The upper limit was imposed by the longest wavelength for which S_λ is at least 1% of its peak value. Spectral transmittances were determined from spectral density measurements made on a Cary Spectrophotometer, Model 11. Each lens was carefully positioned in the sample compartment so that the spectrophotometer's essentially collimated reading beam, reduced to a 3-mm diameter, passed axially through the lens. The transmitted light was concentrated on the cathode of the instrument's reading-beam photomultiplier tube by a thin simple lens. With the camera lens absent, a zero reading also was made through this thin lens, adjusted in position to cause the same cathode area to be used.

The influence of lens transmission on color balance is determined by the ratios of its three actinic transmittances as evaluated by the blue-, green-, and red-sensitive emulsions of the color film. A photographically neutral lens will have no influence on color balance. A lens which reduces the actinic efficiency of radiant energy as it affects the blue-sensitive emulsions, but not as it affects the green- and red-sensitive emulsions, will produce pictures with relatively yellow color balance. Absorption of ultraviolet energy has this effect, and the greater the absorption, the yellower the balance becomes. If, in addition, there is absorption of green light, the balance will move toward red rather than yellow.

Figure 1 shows graphically the computed color-balance relationships among the 79 lenses. Logarithmic scales are used on both axes, appropriate to the facts that the significant quantities are ratios, and that photographic exposures are ordinarily compared on a logarithmic basis. The coordinates are chosen to agree with the directions of color change

Communication No. 2062 from the Kodak Research Laboratories, received 29 October 1959.

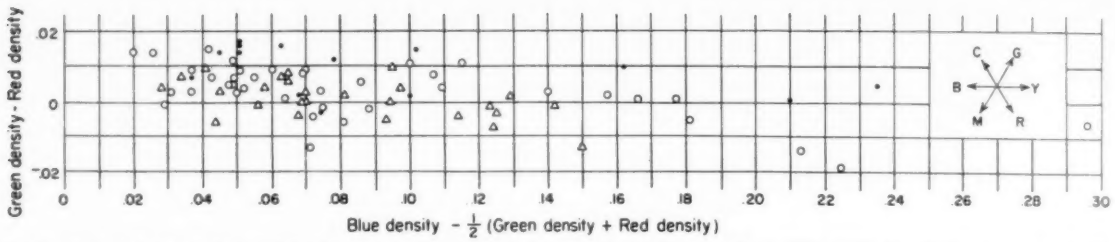


Fig. 1. Computed color-balance relationships among color transparencies made with 26 sheet-film camera lenses (△), 39 roll- and miniature-film camera lenses (O), and 14 motion-picture camera lenses (•).

shown in the chart's inset diagram. The origin (O, O position) is the point which would be occupied by a perfectly neutral lens. Absorption solely of ultraviolet energy changes only the lateral position of a lens plot. Differences in vertical position usually are largely, but not entirely, due to surface coatings. On this chart, a change of 0.10 in position is approximately the effect of a Kodak CC10 filter of the indicated color.

The lenses have been separated, in the figure, by symbol according to their major uses as commercial lenses (largely for sheet-film cameras), roll-film and miniature-film camera lenses, and motion-picture camera lenses, including lenses for 8, 16, and 35mm cameras. It is notable that lenses for roll-film and miniature-film cameras are scattered throughout the range of colors, and indeed include the widest variations.

An effort is being made in the photographic industry to restrict new manufacture to a smaller range of colors. A committee of the American Standards Association (PH3.3) has submitted a proposal for a standard method of measuring and specifying lens color, to aid lens manufacturers in controlling the color effects of lens components and assemblies. Camera lenses are long-lived, however, and photographers must expect that their favorite old lenses may have photographic color effects far enough from the normal, for which color films are designed, that correcting filters are advisable.

• Book and Journal Reviews

Modern Geometrical Optics

MAX HERZBERGER, Vol. 8 of *Pure and Applied Mathematics*, Interscience Publishers, Inc., New York, 1958, 500 pp. + xii pp., 9 by 5¾ in., $15.00

Applied Optics and Optical Design, by A. E. Conrady, served to inspire former generations to take up the trade of optical design by treating specific optical systems by trigonometric methods. Conrady presented a systematic approach to lens design, defined the aberrations and pointed out their theoretical and practical limits. *Modern Geometrical Optics* now further inspires an advanced generation of optical scientists and designers by giving a rigorous mathematical approach and tools, and by reducing these to practice for modern high-speed digital computer methods. It is logical that this book has come from the significant life-time work of Max Herzberger.

Since World War II, optical lenses and instruments have played an increasingly important part in our rapidly advancing technology in scientific and military areas. The book under review is the first comprehensive treatise to give the designer of optical instruments a deeper understanding of the theory of optics and the mathematical tools and methods necessary for the modern design of quality instruments.

The book is composed of ten parts. Part I describes the method of tracing rays through an optical system. The formulas presented are especially developed and adapted for use with high-speed electronic computers. Independent checks and controls are added to point up machine errors.

Part II is concerned with the precalculation of the optical system (Gaussian optics) leading to a preliminary or first-order solution for the lens which at this point is corrected for Petzval sum and longitudinal and lateral color aberrations. An important new tool called Gaussian brackets is introduced which enables the designer to investigate the effect of small changes in the system. By making these changes and knowing their effect, we can reach the desired preliminary solution.

In Part III the general laws of optical image formation are derived from the ideas of Hamilton. It is a clear and orderly development. The author emphasizes the study of the different types of imagery.

With the background of Parts I and II, and the for-

mulas, methods, and ideas developed from the laws and theories of Part III, the author specifically treats concentric systems in Part IV. He recognizes that a knowledge of concentric systems is of great value to the designer, and even though the field is limited, it can be given a complete mathematical treatment.

It is in Parts V through VIII that the author makes original and significant contributions to modern geometrical optics. The most frequently employed lens system in optical design is a rotation-symmetric system. Part V shows the specific form which the methods and general laws of Part III assume in systems with symmetry of rotation. Since rotation-symmetric systems are complex, a complete mathematical treatment is not possible. Therefore, the author derives a general theorem of many applications which enables the designer to investigate the limitations of optical image formation.

The methods developed in the book thus far permit the results of Gullstrand's work to be derived in Part VI. From this work an approximation theory develops for normal systems along a principal ray. This leads to the development of a new image-error theory in Part VII, which is the heart of this treatise. The theory combines third- and fifth-order aberrations for the neighborhood of the axis. Then, to quote from the text: "Finally, in Part VIII we develop a mathematical model of an optical system. The results of tracing a few rays, both meridional and skew, from several object points are fitted to a fifth-order formula equivalent to the theory discussed in Part VI. This formula is then used as an interpolation formula to calculate the intersection points of a large number of rays with one or more image planes. The rays are evenly spaced over the exit pupil, and therefore the plots of the intersection points, called spot diagrams, give a record of the distribution of light over the selected image planes. These spot diagrams are treated as vector sums of simple diagrams, and they serve as a new tool in lens design, giving a record of the behavior of all rays from each of the selected object points."

Part IX briefly discusses geometrical optics in inhomogeneous media based on starting with Fermat's principle instead of the laws of refraction and reflection.

Part X is a mathematical appendix giving derivations as well as numerical examples on the tracing of skew rays, and tracing of astigmatism and asymmetry. A chapter of the appendix is devoted to a very interesting and informative historical summary followed by a comprehensive bibliography of some 150 relevant publications.

Modern Geometrical Optics covers the subject with clarity and completeness and is itself a tribute to Max Herzberger and invaluable in the field of optical design.

This book is highly recommended to all who are interested in applied geometrical optics, whether they be optical designers, librarians, teachers, students, scientists, or users of optical instruments.—*David C. Gilkeson, Wollensak Optical Co., Rochester, N.Y.*

Eye, Film, and Camera in Color Photography

RALPH M. EVANS, John Wiley and Sons, New York, 1959, 410 pp. + xii pp., 107 b-&-w, 16 color illus., 6 by 9¼ in., $8.95

The chemist or physicist, accustomed to thinking in terms of equations and precise physical relationships, may read this book with a feeling of frustration. He will find it essentially devoid of mathematics and equations. He may also find it somewhat contrary to his training to accept that what the eye sees in looking at a scene and an "accurate" color photograph of that scene cannot be precisely related to each other. Nevertheless, Mr. Evans will probably succeed in convincing both our scientist and the layman that this is the case. It becomes evident in the first few pages that the author speaks with authority from a thirty-year background in the psychophysical aspects of color photography.

The author's avowed purpose in writing this book was to discuss in detail those factors which affect the observer's reaction to a photograph. He explains such factors as depth, perspective, binocular vision, object-space relationships, color perception, brightness range, saturation, hue, and the significance of these factors for the observer. What the observer sees in a color photograph of a scene is further influenced by new factors, such as the geometry of the imaging process, the dye chemistry of the color process, and the quality of the light used to make and view the reproduction. He points out that the eye is very poor as an absolute measuring instrument, although training can accomplish a great deal. Witness the professional photographer who scorns use of an exposure meter, yet produces remarkably uniform exposures.

After establishing such background and reviewing the basic principles of additive and subtractive color processes, Mr. Evans demonstrates with both words and photographs that the photographer can markedly affect the impression the color photograph will create by exercising control over the geometrical, photometric, processing, and viewing conditions. He has included a number of comparative photographs which nicely illustrate the points under discussion. For example, a striking pair of photographs demonstrates the effects of diffuse and specular illumination on a polished copper kettle.

This reviewer concluded Mr. Evans's book with mixed emotions. Many of the points made are sufficiently related to everyday experience that there is danger of feeling that this is old stuff. On the other hand, the thorough elaboration of the author's points, done in very readable language, will give even the most practiced professional additional insight into the medium of color photography. The book represents a comprehensive qualitative treatment of a complex subject. It ought to be required reading for all who would like to exercise control over the visual impression that their color photographs will create.—*Hutson K. Howell, Itek Corp., Boston*

The Audio Cyclopedia

H. M. TREMAINE, Howard W. Sams & Co. and the Bobbs-Merrill Co., Indianapolis, 1959, 1269 pp., 6 by 9 in., profusely illustrated, $19.95

The format of this encyclopedic work is interesting in that it lends itself both to leisurely perusal and quick location of specific information. The 26 sections that comprise the book cover essentially the entire field of audio. Each section contains a series of numerically coded questions followed by generally concise, articulate answers. The order of questions, by-and-large, follows a logical exposition of the section subject, starting with the more general aspects of the subject and leading to the more specific. Specific items of interest may be located quickly by consulting the 54-page index which lists both page number and question code number.

The 1269 pages, including index (not 1280 as claimed on the jacket), represent an extensive compilation of

information on audio recording and reproduction techniques. The book treats the fundamental concepts of sound waves, their complexities, behavior, and the equipment associated with their recording and reproduction. The author's extensive background in the motion-picture industry is evident from the large amount of information relating specifically to that field. Four of the sections are devoted to aspects of audio engineering that may be considered essentially phases of motion-picture recording (Motion Picture Projection Equipment, Optical Film Recording, Magnetic Recording, and Constant Speed Devices). However, all sections of the book should be of interest to the photographic engineer who is in any way concerned with audio.

The profusion of illustrations (over 1600) clearly complement the text. Although the preface claims that circuit diagrams and illustrations throughout offer workable circuits with practical component values, the reader will not always find component values listed. In general, however, each illustration is complete within itself.

Any encyclopedic work is doomed from the beginning to be partially inadequate by virtue of incomplete and inaccurate treatments which seem, inevitably, to creep into such publications, and the present book is not without its share. Since it is the work of one man, it is perhaps surprising that the objections and criticisms to the book are not more numerous than they are. The most serious objection this reviewer finds relates to the inadequacy of documentation and referencing throughout the whole book. References are not cited in the text itself but appear at the end of each section, listed according to question code numbers. The reader must go to the end of the section in order to find out what, if any, references are listed for a particular question. The reference lists could in no way be described as extensive. They are, in fact, generally inadequate, citing, as they do, only a few primary and key secondary sources. Some general bibliographical material may appear at the end of a section following the list of references but both reference lists and bibliographies typically are too incomplete to suit the needs of the serious reader who wishes to find more complete or more specific sources of specialized information.

Although gross inaccuracies do not appear to be in evidence, there are a disconcerting number of instances when oversimplification and ambiguity lead to erroneous implications or statements that, lacking necessary qualification, stand in error. On page 635, for example, question 18.172 asks: "What is the loss per generation of re-recorded film?" and is anwered with only the simple statement that: "For each generation, approximately 80 per cent of the resolving power remains." To imply that the loss of resolving power through generations of duplication is a simple exponential function is not only ambiguous but also incorrect in its oversimplification. Similarly, the definition of a photometer, on page 634, as "a photocell of the self-generating type ...." is unduly incomplete and incorrect. In section 18.196 ("What is a densitometer?") only two instruments are mentioned, "the Eastman Kodak Capstaff-Purdy visual densitometer" (Eastman Densitometer, Transmission Type) and the Westrex Model RA-1100 F. It is understandable that two instruments representing the major differences in receptor schemes should be mentioned, but it is not completely understandable why one of these examples (the Eastman Densitometer) should be an instrument that has been discontinued for over eleven years. A minor point is that the photoemissive tubes of the Westrex densitometer are incorrectly referred to as "photocells." There are some instances of transposed figure captions, such as with figures 23.141 B and C, and an occasional omission of part of the figure or caption, as on page 1054.

Inevitably, there are a few circular wild-goose chases such as with question 18.263: "What is a P-2 developer?"; answer: "A special developer formulated for variable-area sound negatives . . . see Question 18.300." Question 18.300 shows pictures of sound-tracks developed in both "P-1" and "P-2" developers and refers the reader to question 18.232 which discusses cross-modulation testing. At this point, the reader is at least pointed in the right direction, but if he finds his interest sufficiently piqued he has no other choice but to search the index where he will find reference to the original "P-1" and "P-2" questions plus two other questions which list formulas for "typical" variable-area and variable-density sound track developers. If he assumes that the "typical variable-area" formula refers to the P-2 solution he will be in error. Adequate referencing does not exist and nowhere in the book does the author explain that the "P-2" developer harkens back to the 1939 RCA aluminate developers and their successors. In fact, if the reader really wants a specific answer to the question "What *is* a P-2 developer?", he will not find it in this volume.

However, when one considers the size of this work and the amount of material covered, these objections can only be considered enough to indicate that the book is not perfect. With the exception of the inadequate reference lists, the faults of the book generally are merely annoying flaws rather than completely disabling factors. The useful and accurate material contained far outweighs the drawbacks in this book which should make a valuable addition to the reference shelf of anyone with a technical interest in the broad subject of audio.—*C. J. Bartleson, Eastman Kodak Co., Rochester, N.Y.*

The Elements of Style

WILLIAM STRUNK, JR., With Revisions, an Introduction, and a New Chapter on Writing by E. B. WHITE, Macmillan, New York, 1959, 71 pp. + xiv pp., cloth, $2.50, paper, $1.00

This little book, in a mere 71 pages, contains a wealth of information and good advice on how to write clearly, accurately, and concisely. The book is not directed to the writing of scientific and engineering papers, but its contents are certainly applicable. The first four chapters, "Elementary Rules of Usage," "Elementary Principles of Composition," "A Few Matters of Form," and "Words and Expressions Commonly Misused," are reproduced with slight revision from Professor Strunk's original book, which was privately printed in 1918. The revisions were made by E. B. White, who has added a chapter, "An Approach to Style," worthy of the first four.

William Strunk, Jr., favored a direct, precise style well suited to scientific writing. "Vigorous writing is concise. A sentence should contain no unnecessary words, a paragraph no unnecessary sentences, for the same reason that a drawing should have no unnecessary lines and a machine no unnecessary parts. This requires not that the writer make all his sentences short, or that he avoid all detail and treat his subjects only in outline, but that every word tell."

The book is well worth the time required for a careful reading of its rules and suggestions, and a careful study of its examples. The time spent will benefit both a writer and his readers.—*T. H. James*

Journal of the Society of Scientific Photography of Japan

Vol. 22, No. 2, June 1959 (in Japanese)

Résumés by S. Kikuchi and T. H. James

Negative – Positive Color Printing Processes

SHOJI HAGIWARA AND SHIGERU HASEGAWA (Oriental Photo Ind. Co., Ltd., Nishiochiai, Shinjuku, Tokyo), pp. 63–69

A review with 18 references, all to English and German language sources.

Studies on Color Television Recording: II — Relations Between Color Film Images and CRT Images

HIDESABUROU GENDA AND SOUICHI KUBO (Chiba Univ., Matsudo, Chiba), pp. 70–74

In Part I (*ibid.*, **22:** 33–37), the authors compared color television with various systems of color photography. In this paper, they discuss the transfer characteristics from color film to the tricolor cathode-ray tube and determine transfer gradients for Agfa, Eastman, Fuji, and Konishi positive color print films. The dyes used in color film have a certain amount of unwanted spectral absorption that has a considerable influence on the transfer gradient and color reproduction qualities.

Solarization with Gamma Rays and Electrons

AKIO MIYAUCHI AND YASUO SHIMIZU (Fuji Photo Film Co., Ltd., Minami-Ashigara, Kanagawa Pref.), pp. 75–77

Ehrlich (*J. Opt. Soc. Am.*, **46:** 801 (1956)) found that the reciprocity law for x-ray exposures does not hold in the solarization region; the solarization increases with decreasing x-ray intensity. The present authors have found that the reciprocity law does not hold in the solarization region for gamma-ray and electron exposures.

Fuji Medical X-ray Film was exposed to gamma rays from cesium-137 and cobalt-60; the intensity was varied by varying the distance of the film from the source. The film was developed in a Metol – hydroquinone – ascorbic acid surface developer. Characteristic curves and reciprocity plots are given for the Co-60 exposures over a range of 3 min to 216 hours. The characteristic curves show the normal region of ascending density, a region of decreasing density (solarization), and a second region of ascending density with increasing exposure. The reciprocity law holds in the normal region of increasing density but not in the second region of increasing density. In the solarization region, reciprocity failure is marked and an optimum intensity for production of maximum solarization occurs. This intensity produces minimum density in 16 – 28.5 hrs. Since the longest exposures were for 216 hours, the authors thought that a change might occur in the nature of the latent image over this period and that this might account for the lower degree of solarization at the longest exposure times. However, they found that when the film was exposed for 16 hours, stored until a total of 216 hours had elapsed, and then developed, solarization was more pronounced than when the film was developed immediately after the exposure. The reciprocity plots for Cs-137 exposures show characteristics similar to those for the Co-60 exposures.

X-ray film was exposed to a 50-kv electron beam in an electron microscope for 0.005 to 10,000 sec. Characteristic curves and reciprocity plots are given. The reciprocity law holds in the normal region of ascending density, but reciprocity failure occurs in the solarization region. The degree of solarization increases with decreasing intensity.

The authors suggest possible explanations for their results, but withhold conclusions until more experimental evidence is available.

The captions of Figs. 2 and 3 should be interchanged.

Photographic Sensitivity of Silver Azide Emulsions

YOSHITADA TOMODA (Govt. Chem. Ind. Research Inst. Tokyo, Hiratsuka-shi, Kanagawa Pref.), pp. 78–82

Silver azide emulsions were prepared without ripening, and their developability and sensitivity to light and gamma rays were studied. The emulsions were prepared from four solutions: **I**, 1 gram gelatin, 20 cc water; **II**, 1 gram NaN_3, 25 cc water; **III**, 2 grams $AgNO_3$, 25 cc water; **IV**, 2 grams gelatin, 10 cc water. In a typical preparation, solution **II** was added to solution **I** at 40° C with agitation, solution **III** was then added over a period of 5 min, and finally solution **IV** was added. The emulsion was coated on glass plates, 1.5 cc on a 3 by 12-cm plate. The emulsions were developed in weakly alkaline Metol developers; sodium sulfite was avoided because of the solubility of the silver salt. A suitable developer consists of 3 grams Metol, 2 grams ascorbic acid, 2 grams Na_2CO_3 1 gram NaCl, and water to make 1000 cc; development time at 20° C is 6 min.

The emulsion prepared with an inert gelatin showed a higher sensitivity to light than those prepared with active gelatins. The emulsion sensitivity decreased with increasing temperature of mixing over the range 40° to 60° C. The sensitivity increased slightly with increasing excess azide content up to a certain point, and decreased at higher azide content. The method of mixing the solutions in the preparation of the emulsion has an effect on the photographic properties. Emulsion **A**, prepared by adding the $AgNO_3$ solution to the combined gelatin and NaN_3 solution, showed a higher sensitivity and lower contrast than emulsion **B**, prepared by adding the $AgNO_3$ and NaN_3 solutions simultaneously to the gelatin solution. Emulsions with a high concentration of AgN_3 had the largest grains. The addition of suitable amounts of oxalic acid, citric acid, and tartaric acid increased the sensitivity of the emulsions to both light and gamma rays. Development was accelerated by monoethylamine (e.g. 30–50 cc of a 2% solution added to a developer of 4 grams Metol, 2 grams ascorbic acid, 3 grams borax, and 1 gram NaCl per liter).

The most sensitive emulsions prepared showed sensitivities to light and to gamma rays in between those of silver tungstate and silver chloride emulsions. The silver azide emulsions were made developable by cobalt-60 gamma radiation of 10^4 to 10^5 r.

Effects of Minute Quantities of Lead Salt on the Photographic Emulsion, Part IV

YASUO WAKABAYASHI (Konishiroku Photo Ind. Co., Ltd., Tokyo), pp. 83–87 (Previous papers in the series, *ibid.* **20:** 49, 102, 137 (1957); see also *Phot. Sci. & Eng.*, **4:** 1 (1960).

The author studied the photographic effect of a small quantity of lead salt in a very fine grain AgBr emulsion and in AgBr crystals prepared from the melt. He prepared the emulsions by the neutral process from $AgNO_3$ solutions which contained 0, 0.004, 0.008, 0.02, and 0.1 mole % $Pb(NO_3)_2$, and tested their sensitivity at three

times of ripening (0, 60, and 100 min) to light, 15-kvp and 63-kvp x-rays, and gamma rays from Co-60. The emulsions showed a maximum sensitivity to x-rays and gamma rays at a lead content of 0.004 to 0.02 mole %. The light sensitivity varied only slightly with the lead content, in contrast to a marked decrease in sensitivity previously obtained for coarse grain emulsions.

The author prepared crystals of AgBr from the melt, using precipitates of the pure salt and of the salt prepared from $AgNO_3$ solution which contained 0.02 mole % $Pb(NO_3)_2$. The crystals were soaked for 30 min in a 10% KBr solution saturated with bromine, then in 10% KBr solution containing 5% semicarbazide, and finally in a 0.5% gelatin solution containing 4×10^{-5} mole/liter $AgNO_3$; they were then ripened at 40° C for 2 hours before exposure. The sensitivity of these crystals to both light and x-rays was greatly decreased by the lead salt; the degree of solarization also was decreased. The author explains the dependence of the sensitizing effect of lead ions upon grain size in the x-ray exposures by assuming that not only interstitial silver ions but mobile surface silver ions contribute to the formation of the latent image.

Psychophysical Treatments of Photographic Optics: I —On the Distance to Observe Pictorial Photographs

MINORU TAMURA (Chiba Univ., Matsudo-shi, Chiba Pref.), pp. 88–90

The distance for proper observation of exhibited pictorial photographs might be judged on the basis of the distance at which the viewer obtains correct perspective, or in terms of the angle of view at which the human eye can encompass the photograph. The best angle of view should be less than 30°. The author made a statistical study of the distance at which viewers observed salon photographs in 19,609 cases. He plotted the diagonal, d, of the photographs against the viewing distance, l, in centimeters, and found that the points were roughly represented by the curve:

$$d = 0.00885\, l^2 - 0.02\, l - 4.03$$

Factors which influenced the observation distance were: (1) The height of the photograph (the optimum observation distance was greater for a vertically-hung photograph than for a horizontal one); (2) physical conditions (the observers came closer to the photographs when the luminosity was low); (3) the content of the photograph; (4) personal conditions.

Graininess and Granularity of Photographic Materials

SHINGO OUYE, pp. 91–99; continued from No. 1, pp. 38–47

A review with 104 literature references, mostly to American and European sources.

Zhurnal Nauchnoĭ i Prikladnoĭ Fotografii i Kinematografii

Vol. 4, No. 5, September-October 1959 (in Russian)

Résumés by S. C. Goddard

The Relation Between Digestion and Aging of Photographic Materials

S. M. SOLOV'EV, pp. 321–328

A standard ammoniacal emulsion was ripened, washed, and digested, samples being taken after 1, 2, 3, 4, etc., hours' digestion. Each sample was split into four parts before coating: (1) no sensitizer or stabilizer added; (2) with sensitizer (3,3′-dimethyl-4,5,4′,5′-dibenzo-9-ethylthiacarbocyanine chloride) but no stabilizer; (3) no sensitizer but with stabilizer (5-methyl-7-hydroxy-2,3,4-triazaindolizine); and (4) with both sensitizer and stabilizer. The coated samples were stored for varying lengths of time before sensitometric tests were made. Curves showing the variation of speed with keeping time were constructed. Similar experiments were performed with a panchromatically sensitized (9-ethylthiacarbocyanine with two substituents in the hetero-nuclei) and with an infrared sensitized (3,3′-diethylthiatricarbocyanine iodide) emulsion. The curves indicate that in an emulsion without stabilizer or sensitizer, the aging process is similar to an extended digestion, while the introduction of a stabilizer or sensitizer distorts the course of aging or alters it completely.

A set of experiments was carried out in which the non-halide silver was estimated at intervals during storage of the samples. These showed no change in non-halide silver in cases where a rapid fall of speed was evident. The fall of speed in the sensitized emulsions is ascribed to the action of bromine, liberated in the decomposition of silver bromide, on the sensitizing dye to give a strong desensitizer.

Natural Absorption in Silver Halide

M. M. VORONTSOVA, pp. 329–333

The natural absorptions of silver chloride and bromide lie mainly in the ultraviolet and decrease at longer wavelengths: within the width of the band, two quite intense and clearly defined maxima were found, at about 250 and 270 mμ for silver chloride and 270 and 305 mμ for silver bromide. In all probability they may be connected with the excitation and ionization of halide ions of the normal crystal lattice.

The long-wave edge of the absorption curve is due to a considerable extent to centers connected with a stoichiometric excess of silver. It may be connected in part with foreign atoms or ions.

The region about 370 mμ for silver chloride and 400 mμ for silver bromide may be taken as the beginning of the absorption of the crystal lattice of these salts itself. (*Translation of author's abstract*)

Studies in Densitometry: II — Scattering of Light by Developed Photographic Papers

I. M. DAVYDKIN, pp. 334–340

Scattering indices for light reflected from the surface of a developed photographic paper depend to a marked degree on the character of the paper surface: with increasing gloss the paper develops a sharply defined specular reflection component. Scattering of light by developed densities on the paper alters with changes in their optical density in such a way that the degree of deformation of the scattering index increases with increase in the optical density. Change in the angle of incidence of the beam of light on the sample alters the scattering index; for glossy and very glossy papers the coefficient of brightness in the direction of specular reflection grows with increase in the angle of incidence. A quantitative characteristic for the gloss of photographic papers is proposed and is expressed by a single figure. From the scattering index a determination was carried out on the gloss of density samples and the limits of variation of gloss for papers with different surfaces were established. (*Translation of author's abstract*)

Studies of the Temperature Dependence of Photographic Development: IV — The Relation Between the Energy of Activation of Development and the Selective Action of Developers

V. I. SHEBERSTOV, pp. 341–344

Cases in which the energy of activation of fog development is equal to, or less than, the energy of activation of image development, but in which, nevertheless, developing action is selective, cast doubt on the hypothesis that selective action is determined by a greater energy of activation for fog development than for image development. The equation derived in earlier papers for the selectivity of development in terms of energies of activation also contains constants representing the *rates* of development of fog and image. When the equations are analysed, taking these factors into account, it is shown that cases are possible in which the rates of development ensure selectivity, although the energies of activation would either imply equal development of fog and image or even preferential development of fog.

Studies on the Ability of Photographic Materials to Reproduce the Small Elements of an Optical Image: II — The Influence of the Conditions of Positive Printing on the Resolution of a One-Dimensional Lattice

U. K. VIFANSKIĬ AND YU. N. GOROKHOVSKIĬ, pp. 345–355

The resolution in a positive image under any conditions of carrying out the positive process is lower than in the negative image. When the contrast of the subject (a one-dimensional test object) is lowered, the difference between the resolutions in the negative and the positive images also falls. This holds for both contact and projection printing at any scale of enlargement. In projection printing, the resolution in the positive image increases as the scale of enlargement is increased, tending towards the value of the resolving power in the negative image. As the contrast of the negative material is increased, the difference between resolution in the negative and in the positive images, with constant conditions of printing, decreases. Within fairly wide limits, the contrast of the positive materials has practically no influence on resolution in the positive image obtained from a given negative under optimal printing conditions. Negative exposures to give optimal resolution, evaluated both from the negative and from the positive images, coincide. (*Translation of author's abstract*)

The Correcting Effect (Dot Etching Quality) of Photographic Materials

I. A. NOVIKOV, pp. 356–362, 1 plate

By the correcting effect of a photographic material is meant its ability to compensate to a certain extent for loss in density of a halftone dot during dot etching. A numerical value was given to the property by measuring, with a special reticule in the eyepiece of a microscope, the diameter of an etched dot in which the grains in the core of the dot just prevented the passage of background light.

This correcting factor was found to be unaffected by the conditions under which development and dot etching were carried out but was very markedly affected by the properties of the emulsion layer itself. The correcting effect became greater as the silver halide content of the material was increased. The correcting factor was also increased as the covering power of the emulsion and the gelatin-to-silver ratio increased. The essential condition for good etching properties is shown to be the presence of the halo surrounding the dot.

A Method of Evaluating the Quality of Stereo Projection on a Grid-Type Stereo Screen

L. V. AKIMAKINA, pp. 363–366, 3 plates

The quality of grid stereo screens is determined by the dimensions of the working region for the central and side zones of stereo vision and the magnitude of the coefficient of separation of the images of the stereographic pair. The magnitude of the separation coefficient depends not only on the quality of the lenticular screen but also on the reflecting surface and on the adjustment of the grid with the reflecting surface. The coefficient of separation is a characteristic of the quality of perception of a stereo image and the parameters of the working region of the zone determine the degree of ease of perception of a stereo image on a grid stereo screen. (*Translation of author's abstract*)

The Calculation of an Optical System for Combining a High-Speed Cine Camera with Shadow and Interferrometric Apparatus

E. A. TARANTOV, pp. 375–379

The Influence of Bromide Ion Concentration on the Optical Sensitization of Photographic Emulsions

A. V. BORIN (Letter to the Editors), pp. 380–381

An emulsion, not sensitized with gold, was spectrally sensitized with a dibenzothiacarbocyanine (**I**) and a disubstituted thiacarbocyanine. For the emulsion sensitized with dye **I**, increase in pBr by the addition of silver nitrate either before or after the introduction into the emulsion of the dye caused a considerable increase in speed. Lowering the pBr of the emulsion either before or after the introduction of the dye led to a decrease in speed. It is concluded that the aggregation and precipitation of the dye is not the only factor affecting the speed, the bromide ion concentration also having some effect on the sensitization.

The Relation Between the Low Intensity Sensitivity of Photographic Layers and Some Emulsion Factors

P. V. MEĬKLYAR, V. M. SHVARTS, AND Z. V. KHARITONOVA (Letter to the Editors), pp. 381–383

Two panchromatic emulsions, one an ammoniacal emulsion and the other neutral, were used for a study of the factors influencing the speed of emulsions used at low lighting intensities, such as those for astronomical use. Increasing the pBr caused the minimum of the reciprocity failure curve to move towards the longer exposure times, the speed at low lighting intensities being increased. The curve for the kinetics of digestion was found to vary with the exposure time used in making a speed test. As this time was increased from $\frac{1}{20}$ sec to 50 min, the optimum digestion time increased but the optimum speed fell. As digestion was continued beyond the point of optimum speed for an exposure of $\frac{1}{20}$ sec, the difference between the speed for $\frac{1}{20}$ sec and 50 min decreased considerably. An explanation of the findings is given in terms of Meĭklyar's theory of the thermal ionization of photolytic silver atoms.

[*Abstracts of remaining material in the September-October 1959 issue of* Zhur. Nauch. i Priklad. Fot. i Kinematografii *will appear in the next issue of* Photographic Science and Engineering.]

PHOTOGRAPHIC SCIENCE AND ENGINEERING
Volume 4, Number 2, March-April 1960

• New Products and Developments

FRANK SMITH

• Cameras and Accessories

Fairey Aviation Co. Ultrawide-Angle Aerial Camera

An ultrawide-angle 35mm aerial camera, called the WRETAR, has been developed by the Fairey Aviation Co. of Australasia Pty. Ltd., Salisbury, South Australia, in collaboration with the Weapons Research Establishment, Salisbury. It is designed for use in target aircraft to provide photographic evidence of interceptions. The records give accurate information on distance relative to target aircraft and attitude, together with other data needed to assess the performance of guided missiles. Data of this kind, related to the incorporated time scale, records the timing of an event such as the operation of a proximity fuse.

The camera uses the WRE Ultrawide-Angle Lens, which gives a field of view in excess of 180° and provides an almost linear relationship between radial reading and true radial angle. Full spherical coverage is possible by employing two cameras mounted with lenses facing in opposite directions.

Aligned axially, two cameras can be accommodated in a pod of 5.5 in. in diameter. Running at approximately 100 frames/sec, the exposure time is fixed at 1 msec. The running time is approximately 12 sec, but this can be extended to 20 sec by using thin film.

The system has an $f/11$ effective aperture and includes an X-2 yellow filter. The camera, which is 5.32 in. in diameter by 19.65 in. long, weighs 15 lb when fully loaded with 100 ft of standard film.

A single-shot version of the camera, the WRECISS, also equipped with the ultrawide-angle lens, has been developed for installation in missiles to record target interception. The shutter of the WRECISS camera, which provides an exposure of 0.5 msec, is operated by the firing of an electric fuse. The system has an effective relative aperture of approximately $f/8$ and the camera is sufficiently robust to ensure satisfactory recovery of the film after missile impact.

The WRECISS camera is 1.5 in. in diameter and 1.2 in. long and weighs 9 oz.

EG&G Underwater Photographic Equipment

New underwater photographic equipment, designed for operation at the greatest known ocean depths, has been developed by Edgerton, Germeshausen and Grier, Inc., 160 Brookline Ave., Boston 15. It consists of a 35mm camera and a 100-wsec light source, mounted in separate watertight housings. The camera accepts a 100-ft roll of 35mm film on a daylight loading spool. Two models are available: the CA-9 Camera and LS-9 Light Source, for use at depths to 36,000 ft, and the CA-8 Camera and LS-8 Light Source, for use at depths to 6,500 ft. Except for differences in pressure-housing dimensions, the units are basically the same.

Positive photographic frame identification is provided with each exposure. A data chamber in the rear of the housing is photographed, recording depth, pressure, time, location, ship, etc.

The equipment can be used in a variety of configurations for single or stereo pictures. A sonar pinger is available for positioning the camera off the bottom. The sonar pinger can be attached, with the camera and light source, to the MT-8 underwater rack.

Kalimar Panoramic Camera

A Japanese 35mm panoramic camera, the "Widelux," which takes a 140° picture on a 24mm by 60mm negative, has been introduced by Kalimar, Inc., 1909 S. Kings Highway, St. Louis. The camera is equipped with an $f/2.8$ lens in a ball-bearing-mounted ring which spins around when the focal plane shutter with speeds of $\frac{1}{2}$, $\frac{1}{30}$, and $\frac{1}{200}$ sec is tripped.

• Illumination

Bureau of Mines Explosion-Proof Flash Unit

The U.S. Bureau of Mines, Pittsburgh, Pa., has developed an explosion-proof flash unit that fires midget photoflash bulbs. Although designed for mine photography, the unit provides safety for picture taking in other hazardous areas. Cylindrical in shape, the unit measures 4.675 by 4.5 in. and weighs 4.5 lb. It can be used with any camera equipped for flash work.

The unit possesses an intrinsically safe electrical circuit, is battery powered by four 30-v hearing-aid cells, and uses No. 5 or Press No. 25 flash bulbs. The socket for the bulb is mounted in a threaded base which screws into the aluminum housing and makes the removal and replacement of bulbs a simple, quick, and safe operation even in explosive methane – air mixtures.

The unit is fitted with an external socket for connection to a synchronized shutter; alternatively, a photocell can be inserted into the external socket and the unit used as a slave, triggered by a master, shutter-operated unit.

The manufacture of the unit is being undertaken by the J. B. Nottingham Co., Inc., 441 Lexington Ave., New York 17.

• Sensitive Materials

Ilford Fine-Grain High-Resolving-Power Aerial Film

A medium-speed (ASA 32 Daylight) panchromatic film called Ilford H.R. Aerial Film has been announced by Ilford, Ltd., Ilford, Essex, England. The film is intended primarily for use in aerial survey work, and is claimed to be particularly useful for survey of desert areas and similar low-contrast terrain. It has been produced to take full advantage of recently introduced survey cameras with lenses of improved light transmission and higher resolving power. Ilford H.R. Aerial Film has a hardened emulsion, coated on clear 0.005-in. shrink-resisting, anti-static safety base.

Although the information contained in this section is compiled from sources believed to be reliable, the author cannot assume responsibility for its accuracy. Publication of the information here is not to be construed as an endorsement or recommendation of the product or equipment described.

Kodak Micro-Flat Plate for Missile Photography

The Kodak Spectroscopic Plate, Type 103-F, for use in ballistics cameras to record position and speed of missiles, uses glass with a front surface having a flatness specification of 0.00002 in. per linear inch. The plates are 190 by 215 by 6 mm and have spectral sensitivity extending from 2400A to 6800A. Front and back plate surfaces have a high degree of parallelism. Further information is available from Eastman Kodak Co., Special Sensitized Products Div., Rochester, N.Y.

• Miscellaneous

General Electric Thermoplastic Image Recording Process

A recording process has been announced by General Electric Co., Schenectady, N.Y., in which an image is formed on a film consisting of a high-melting base, coated with a transparent conducting coating which has on its surface a thin layer of a low-melting thermoplastic. An electron beam is used to lay down a charge pattern on the surface of the thermoplastic film in accordance with the information to be stored. The film is then heated to the melting point of the thermoplastic. Electrostatic forces between the charges on the film and the ground plane depress the surface where the charges occur until these forces are in equilibrium with the surface tension restoring forces. The film can then be cooled below its melting point and the deformations will be frozen into the surface.

The recording process must be carried on inside a high vacuum (pressure about 0.1 μ). Resolution of the thermoplastic film is comparable to that of photographic film; the image can be readily erased and the film reused. The recorded picture can be projected as a full color image or it can be converted to an electrical signal. (*Extracted from "Thermoplastic Recording," by W. E. Glenn*, J. Applied Phys., **30**:1870 (1959).)

Army Map Selector for Quicker Location of Distant Targets

Microfilm maps coupled with an automatic selector give promise of easier and quicker location of distant targets for Army field commanders. The Fairchild Target Map Coordinate Locator, which is being developed by the Fairchild Camera and Instrument Corp., Syosset, N.Y., for the U.S. Army Engineer Research and Development Laboratories, Ft. Belvoir, Va., will select automatically the correct map from a compartment containing more than 11,000 different maps recorded on microfilm. This will be accomplished by the operator's indicating the map coordinates of the point to be located. The design also calls for immediate projection of the selected map onto a large viewing screen. The whole process, from indication of the map coordinates to the projection of the correct map, will require 15 sec. Accurate grid coordinates of any point on the screen may then be determined by the positioning of horizontal and vertical crosshairs.

The device will be about 6 ft tall, 29 in. deep and 3.5 ft wide, and will weigh about one ton. With the map compartment fully loaded, the Locator will require one-fifth the space now required for storage of the same number of standard map sheets. Automatic selection of the correct map will be considerably faster than manual search and selection of a map sheet.

Maps in the Locator will be 70mm color microfilm pictures of existing maps. Since Army map sheets are a standard size, regardless of scale, maps of varying scales may be stocked in the instrument at one time.

The Locators are intended for use at field army and corps headquarters and by lower echelon units — such as Army missile units — where the accurate location of target points over large areas may be required.

Image Intensifier of 50,000 Over-all Light Gain

Dr. W. L. Wilcock, of Imperial College, London University, at the meeting of the International Commission of Optics, held in Stockholm, Sweden, Aug. 24–29, 1959, described a new image intensifier that has five stages of amplification and an over-all light gain of 50,000.

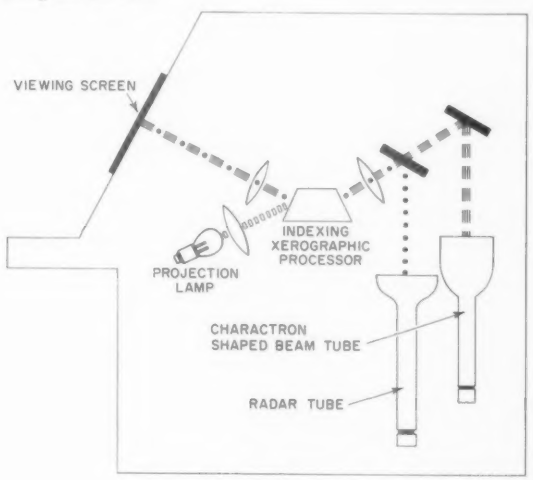
In operation, photoelectrons from the photocathode are imaged on a thin film containing KCl, and secondary electrons are emitted from the back of the film and refocused onto a second film; the electrons from the last stage then go to a fluorescent screen.

Stromberg-Carlson Projection Display System

Electronic equipment capable of displaying alphanumeric, symbolic, and graphic data simultaneously with PPI-type radar presentations has been developed by Stromberg-Carlson, San Diego. The S-C 2000 utilizes a xerographic process called PROXI, developed by Haloid Xerox Inc., to store information gathered from the faces of a Charactron shaped-beam tube and a radarscope. In less than 1 sec from the time the xerographic plate is exposed, the information is projected on the screen of the console. The processor is capable of displaying up to 45 frames/min. As one plate is being exposed, the plate previously exposed is being projected on the console screen. Simultaneously, the other plates are being cleaned and recharged, ready to accept new data for display.

In order to predict future course and position of a target, past history of images can be provided by incorporating an accumulator into the processor. The earlier image then is projected at a lower intensity than the current display. Multicolored displays to provide color differentiation of targets may be provided through use of a multiple projection unit.

The high brightness and high resolution of displayed data allow viewing in normal ambient light directly on the screen of a console or projection for group viewing on a large theater-type screen. A fail-safe feature allows the last frame displayed to be retained permanently, even in the event of complete failure.



PHOTOGRAPHIC SCIENCE AND ENGINEERING
Volume 4, Number 2, March-April 1960

• Advance Program — 1960 Annual Conference

Society of Photographic Scientists and Engineers

Members of SPSE and nonmembers are invited to participate in the 1960 Annual Conference which will be held from May 9 through 13 at the Miramar Hotel, Santa Monica, California. Every effort has been made to group the papers and arrange the sequence of sessions for the convenience of those attending. At this time, the program is as complete and accurate as possible, but experience has shown that minor departures are unavoidable.

Monday Morning, May 9

Data Acquisition, Handling, and Display

Technical Requirements for 70mm Instrumentation Cameras in USAF Missile Programs, *C. B. KRUMM, Aerial Reconnaissance Laboratory, WADD, Wright-Patterson Air Force Base, Ohio*

Improved 70mm cameras are a necessity in USAF missile test programs if high-density intelligence data is to be obtained. Current limitations are imposed by lens – film resolution capability, practical size and weight, object size, distance, and relative speeds encountered. The need for high-speed 70mm recording cameras is outlined and interim methods of extending present capabilities are noted. The utilization of the USAF Type KB-8 70mm strike camera for missile work is discussed and a follow-up program to ruggedize this camera is described. A comparison is made between the relatively simple environment normally encountered in aircraft and the extremely severe environment encountered during missile flight. The effects of this environment on the camera design are discussed. A status report is given on the development of one type of USAF 70mm variable speed instrumentation camera with cycling rates up to 100/sec.

Present and Future Capability of Optical Systems with Emphasis on Ballistic Camera Operation, *GEORGE H. ROSENFIELD, RCA Missile Test Project, Atlantic Missile Range, Patrick AF Base, Fla.*

The three basic optical instrumentation systems for obtaining missile trajectory information at the Air Force Missile Test Center are the Ballistic Camera, the CZR-1 Fixed Camera, and the Askania Cine-Theodolite. They are described and their operation and accuracy discussed. The technique of the use of optical systems for obtaining missile position data is called Intersection Photogrammetry. This concept is described, and error propagation, both random and systematic, is discussed.

Atmospheric Boil and Telescopic Definition, *E. P. MARTZ, JR., Visibility Laboratory, Scripps Institution of Oceanography, University of California at La Jolla, San Diego, Calif.*

Astronomers and missile photographers have long been troubled by the destruction of telescopic images by the irregular small-scale turbulence within the earth's atmosphere. The component elements of this phenomenon are discussed and related to stellar scintillation and the refractive characteristics of the atmosphere. Data are presented to demonstrate the dependence of image deterioration on a considerable number of specific factors. The very serious reduction in telescopic resolution due to loss of image contrast, destruction of the diffraction pattern and defocussing by atmospheric boil is discussed. Observed vs. theoretical resolving power is considered for both practical and ideal telescopic systems acted upon by atmospheric boil. Several methods of overcoming some of the atmospheric image deterioration are presented.

Data Acquisition by Radarscope Photography, *L. F. ALEXANDROWICZ, Aetron Division of Aerojet General Corp., Covina, Calif.*

Described are the problems encountered in the installation of a 35mm sequence camera for recording the cathode-ray tube indicator of a Radar Skyscreen, along with the overlay trajectory image and other essential data. This equipment was required by the Air Force on short notice, and some of the problems pertained to: the dichroic mirror for the overlay superimposition; the elimination of parallax between the overlay and the radar scope; the mechanical installation of the camera for rigidity and for operator and servicing convenience; synchronization; and film and exposure-development considerations for optimum recording of data. Recommendations for a more sophisticated final system have been submitted to the Air Force.

Integration of Photogrammetric and Electronic Data Processing Equipment for Highway Planning, *FREDERICK J. DOYLE, Broadview Research Corp., Washington, D.C.*

The standard photogrammetric techniques of mosaic construction, topographical mapping, and reading of cross-section data are now widely employed in highway planning. Equipment has been developed to record cross-profile data automatically. Computing programs are in use to fit horizontal and vertical alignment to these data. Cross sections may be plotted automatically, and earthward volumes and shoulder planting areas computed. The addition of aerial triangulation to these procedures materially reduces time spent in field survey. Techniques are under development to automatize several parts of the topographic mapping process. Another development will replace the topographic map by a digital terrain model. The ultimate objective is to have machines and computers perform all routine operations, so that human brainpower may be reserved for those decisions requiring sound engineering judgment.

Mobility in Underwater Cinematography, *D. REBIKOFF and P. CHERNEY, Cinefot International Corp., New York 36, N.Y.*

A miniature underwater craft is described which may be ridden by a cameraman and which moves in the water under its own electric power. This 120-lb duralumin vehicle is equipped with a 1.5-hp motor which gives a speed of 2.5 knots. The characteristics and applications of this craft are discussed. It may carry its own lights for photographic purposes and a complete set of instruments for blind navigation in muddy water. In a modified version, the cameraman is enclosed in a streamlined canopy; this version is capable of speeds of 15 to 25 knots and has a cruising range of 25 to 50 nautical miles. An underwater color motion picture will be shown.

Cloud Undercast Presentation for Flight Simulator Operation, *W. B. KLEMPERER and J. E. EKSTROMER, Douglas Aircraft Co., Santa Monica, Calif.*

A cloud projection system has been designed and installed as an adjunct to the Douglas flight simulator for use in jet pilot training centers. Projectors throw the image of a photographically produced cloud panorama on three screens, and these images are made to move in response to the simulated motion of the aircraft. Turning motion and changes of attitude are appropriately reproduced. A short film will be shown to convey the impressions experienced by the pilots flying the simulator.

Monday Afternoon, May 9

Photographic Engineering and Applications

An Investigation of Several Films for Sub-Microsecond Schlieren and Shadowgraph Photography, *SIMEON BRAUNSTEIN, Avco-Everett Research Laboratory, Everett, Mass.*

Seven commercial materials have been evaluated for use at the extremely short exposures encountered in this type of photography. Several spark sources were used, and also a xenon flash tube. Characteristics such as reciprocity failure, speed, fog level, contrast, spectral sensitization, and resistance to forced development are considered.

A New Technique for High-Speed Photography of Cyclic Events, *JAMES R. CHADWICK, Chadwick-Helmuth Co., Monrovia, Calif.*

The use of the "Slip-Sync" for taking slow-motion pictures of high-speed cyclic events is described. A frequency shifted signal from the event is used to trigger strobe lights, (thus yielding a visual slow-motion effect). A 30 ft/sec max 16mm pulse camera operating with this system produces slow-motion pictures duplicating the visual slow-motion effect. Circuits for pulse division enable the camera to operate at some submultiple of the event frequency, this submultiple being automatically selected. The limitations and advantages of this technique are enumerated, the problem of exposure is dealt with, and an application to vibration testing is described.

Magnesium, a Useful Light Source for Sequence and High-Speed Motion Photography, *W. C. FINK, Sylvania Lighting Products, Div. of Sylvania Electric Products, Inc., Montoursville, Pa.*

After a short historical review, including an example of the general engineering principles used in the design of a photographic flash lamp, the aluminum, zirconium, and magnesium-filled flash lamps are briefly discussed. Use of the new magnesium-filled flash lamp for sequence and high-speed motion picture photography will be illustrated by showing slides and motion pictures taken with such lamps. A demonstration of the new lamps will give a realistic impression of their usefulness as "long duration" illuminants.

Interference Comparators for Coordinate Measurement of Ballistic Plates, *A. CHITAYAT, Optomechanisms, Inc., Mineola, L.I., N.Y.*

The requirements, design criteria, and limitations of interference comparators for this application are discussed. Topics treated include monochromatic light sources, signal-to-noise and maximum travel considerations, rates of readout attainable, direction-sensing methods, and means for automatic readout. The device used by Optomechanisms for semiautomatic readout will be described.

Photographic Support for Research and Development of Jet Engines and Their Components, *HOWARD W. HOADLEY, The Marquardt Corp., Van Nuys, Calif.*

The research and development program of turbojet and ramjet engines and their respective components require intensive photographic support. This ranges from routine photographic coverage during initial planning and engineering phases to complex camera installations during static firings and flight testing. Extreme environmental conditions require ruggedized and special photographic equipment. Photographic requirements and design criteria are discussed. Slides and a film will show some of the equipment used for this purpose, its installation in test facilities, and some of the results obtained. Among the problems discussed are instrumentation photography in sea level and high altitude tunnels and cells; lighting; schlieren photography; and turbine blade development, manufacture, and inspection.

Adaptation of Motion Picture Standards to Other Types of Audio-Visual Presentations, *HOWARD W. HOADLEY, The Marquardt Corp., Van Nuys, Calif.*

Audio-visual presentations today consist of many different methods of projection, from many types of projection materials. To meet the demands of quality, quantity, schedule, and costs, techniques used in the motion picture industry for extreme precision in animation have been adapted to other projection media. Legibility requirements, photographic equipment, and methods of production will be presented. Projection equipment, standards, and short-cut and mass-production techniques will be reviewed. A method of producing color slides from black-and-white art work will be outlined and samples shown. Brief consideration will be given to materials and preparation of originals compatible with the techniques outlined.

Tuesday Morning, May 10

Aerial Reconnaissance

Some Practical Applications of Multiband Spectral Reconnaissance, *ROBERT N. COLWELL, School of Forestry, University of California, Berkeley, Calif.*

It is frequently necessary to detect and identify various objects and conditions solely from information collected by sensors that operate in various regions of the electromagnetic spectrum from remote distances. Military photographic reconnaissance, photography of crop diseases, astronomy, use of x-rays, ultraviolet prospecting, and radar and infrared navigation provide many examples. The nature of the desired information determines the part or parts of the spectrum which are used. In "multiband spectral reconnaissance" several remotely situated cameras or other sensing devices, each receiving energy in its own narrow spectral band, may be used in concert to provide information that no single sensor can provide. Numerous slides will be shown to illustrate how this technique may be used to derive many kinds of useful information.

Research Toward Greater Compatibility Between Aerial-Photographic Interpretation and Engineering, *JOHN WALKER, Broadview Research Corp., Washington, D.C.*

This paper discusses basic factors which contribute to the present incompatibility between aerial-photographic interpretation and engineering, with specific reference to the field of highway engineering. Three interrelated areas are concerned with the problem — ground photography, photogrammetry, and aerial photography. Specific areas of concern are discussed in detail, e.g., the effect photogrammetry has had on the photographic materials presently available for photographic interpretation. Ways in which spectral reflectance data may be used in extracting data from aerial photographs are discussed. Specifications can be established for obtaining photographs by the use, for example, of selected film-filter combinations, designed to record the location, quantity, and, in many cases, types of specific images of interest.

The Application of Metrical Panoramic Photography in the U.S. Navy, *LT. GLENN M. BREWER, USN, U.S. Naval Photographic Center, Washington, D.C., and GOMER T. McNEIL, Photogrammetry, Inc., Silver Spring, Maryland*

The techniques which the U.S. Navy is developing to obtain and utilize panoramic photographs will be presented. Applications described will include special purpose reconnaissance and surveillance methods. A discussion of the photogrammetry of panoramic photography will include methods for instant readouts, projection reading, 360° stereo reading from 3 exposures, and accurate topographic mapping. Techniques for processing, viewing, and data reduction will be discussed. The metrical panoramic camera developed by Photogrammetry, Inc., will be described and demonstrated.

All-Weather Aerial Photography, *SQUADRON-LEADER F. L. DUNSCOMBE, RAF, Aerial Reconnaissance Laboratory, WADD, Wright-Patterson Air Force Base, Ohio*

Flight tests conducted over selected targets in the Wright-Patterson Airfield area to study the capabilities of photographic reconnaissance equipment and materials at varying altitudes, in all weather, in poor light, and at twilight, have shown that conventional air photography of high quality can be achieved under adverse weather conditions. The primary intent of this program is to collect data which can be used to increase the operating efficiency of present-day reconnaissance aircraft; consequently standard Air Force equipment and materials have been used throughout the flight tests. Analysis of negatives has shown that good quality photographs can be made in rain with a visibility of less than one mile and at a light level which is 5% of the average figure at this latitude in noon sunshine. Interpretable prints can be made from negatives exposed 15 min after sunset when the illumination is only 1/800th of the average at noon.

KS-50 Panoramic Camera Subsystem, *LEONARD W. CROUCH, Aerial Reconnaissance Laboratory, WADD, Wright-Patterson Air Force Base, Ohio*

Panoramic-type cameras yield the most photographic coverage per unit volume and weight. This approach to the problems generated by increased vehicle performance, operating altitudes, and intelligence requirements is presented, and the KS-50 panoramic subsystem is described. It is capable of resolving a 10-in. object from an altitude of 40,000 ft and it provides data recordings so that photographic scale and position can be recovered off the vertical. These and other features give the KS-50 a potential for charting use, and make it extremely valuable as a supplemental coverage camera for mapping.

Tuesday Afternoon, May 10
Field Trip

Wednesday Morning, May 11
Processing Procedures and Apparatus — I

A Simplified Approach to Automatic Dodging Control in Photographic Printers, *WILLIAM S. FORRESTER, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio; present address, Ramo-Wooldridge Laboratories, Div. of Thompson Ramo-Wooldridge, Inc., Canoga Park, Calif.*

A much simplified means of automatic dodging control is possible by control of the latent image. This is accomplished by directing both actinic and infrared radiation through the negative and onto a photographic emulsion. The actinic light forms a latent image in the usual way while the infrared exposure effects an erasure upon the same latent image. Thin areas of a negative result in strong latent-image formation during the exposure to actinic light; however, these thin areas also permit strongest erasure action, since they also pass large amounts of infrared. As the densities of the negative increase, less erasure is accomplished, resulting in an automatically dodged negative. Recent research has led to many changes in the original concept. These include erasure with other than infrared radiation, pre-exposure of the printing stock, and a study of factors pertinent to an overall upgrading of this approach to automatic dodging.

Model EN-37 Printer, *F. L. LANGFORD, and T. DIXON, Houston Fearless Corporation, Los Angeles, Calif.*

The EN-37 continuous-motion 16mm black-and-white printer has been developed for the Air Force, and is intended for use in making prints from gun camera negatives. These negatives vary widely in density, so a principal feature of the printer is a light modulator controlled by a closed loop servo system. This feature comprises a phototube viewing the light which comes through both the negative and the positive print stock in the printer gate, and an amplifier system driving a Sanborn galvanometer which controls a louver-type light modulator. Other features include a preview station which reads negative density on a meter for use if manual control of the printer light is desired, and a carrying case that may be used as a table for supporting the printer in field use.

Multimask: A New Method of Tricolor Masking, *P. DE PELSMAKER and M. DE RAMAIX, N.V. Gevaert Photo-Producten, Mortsel, Antwerp, Belgium*

As a substitute for the use of several black-and-white or colored masks, a new tricolor mask film, the Gevaert Multimask M14p, has been designed to give a complete color cor-

rection in all types of tricolor reproduction by incorporating the various masks in a single film. The spectral sensitivity and the color coupler of each layer have been chosen so as to give an average correction of every type of deficiency found in the usual dyes and pigments. Different from anything formerly suggested, this is the first material of the kind to reach a commercial status. After exposure, this material needs only a short two-bath color processing. The mask thus prepared gives a contrast reduction and a full color correction for three- or four-color separations.

A Reappraisal of Additive Color Photography, *LIONEL H. WHEELER, Colorvision, Inc., Los Angeles, Calif.*

Justification for a re-examination of additive color is provided by advances in optical and photographic technique. Such advances include dichroic coatings and the "relay" optical system. The Colorvision camera unit and other equipment are described, and applications such as in instrumentation photography with color projection seconds after taking are suggested. A short demonstration film will be shown.

The 20X Precision Enlarger, *R. D. PICKERING, Apparatus and Optical Division, Eastman Kodak Co., Rochester, N.Y.*

This enlarger is designed to produce 9- by 9-in. prints from small sections of 70mm film negatives at a fixed magnification. The aim was to design an enlarger which would reduce the loss of information from the negative to the print to the very minimum. Features include a special specular illumination system, an objective lens whose performance has been maximized over a narrow band of wavelengths in the blue for the specific magnification required, a liquid immersion system for the negative to minimize scratch and dust images, and special measures to avoid vibrations and deflections during exposure. This instrument consistently achieves 400 lines/mm in the central portion of the field, and no lower than 200 lines/mm inside a 9-in. diameter circle on the print.

Analysis of Printer Integrating Circuits, *R. K. RICKARD, Apparatus and Optical Division, Eastman Kodak Co., Rochester, N.Y.*

The basic circuit of an automatic exposure control device for a printer consists of a capacitor, a vacuum photocell, and a thyratron. The capacitor integrates the light coming through the negative and the voltage rise is used to fire the thyratron which, by means of a relay, terminates the exposure. In the ideal case, the printing paper is given an average exposure which is independent of the transmission of the negative and of variations in the output of the printing lamp. It is the purpose of this paper to analyze the effects that practical circuit components have on the accuracy of this circuit in terms of the circuit values used, the leakage resistances which may arise, the background illumination arriving at the photocell, the residual charge remaining in the "discharged" capacitor, and the uncertainty in the firing point of the thyratron. In conclusion, some recommendations are given for the design of a circuit with an accuracy of 1%.

Wednesday Afternoon, May 11

Processing Procedures and Apparatus — II

An Investigation of Print-Out Paper, *J. H. JACOBS, Research Div., Consolidated Electrodynamics Corp., Pasadena, Calif.*

The problem of obtaining rapid access to photographic oscillograph data is outlined. Print-out paper has been used for such recording but it normally requires exposure to ambient light for about 1 min. Attempts to speed up this "latensification" process by increasing the light intensity only fogged the record. A spectrographic study has shown that, while a broad band of radiation may be used for latensification, a relatively narrow band is responsible for the fog. It was found possible to achieve latensification in a few seconds with the use of a special lamp which does not radiate in the fog band. Practical tests and a theoretical study indicated that the fog band could be entirely eliminated by operating at an elevated temperature, permitting latensification in under 1 sec using the more generally available broad spectral band lamps. The theoretical background is presented and some equipment in which the process is used is briefly described.

Commercial Monobath, *HARRY S. KEELAN, Cormac Chemical Corp., New York, N.Y.*

A brief history of monobaths is given, and the properties necessary for a successful commercial monobath are discussed. The advantages of monobath processing over the more conventional multibath technique are related and practical applications to which monobath processing is especially suited are described. These include field work where time and water are scarce and machine processing in which one may expect great accuracy of results with a minimum of temperature and time control. The application of monobaths to such industries as photofinishing and motion-picture, industrial and medical x-ray, and microfile processing is discussed.

The Determination of Control Limits for Photographic Processes, *DONALD THOMAS, Paper Service Div., Eastman Kodak Co., Rochester, N.Y.*

There is a continuing trend towards more critical, higher-speed photographic processes, particularly for use with color materials. These modern processes require control systems with accurately determined limits. The steps required in a typical control system are described, and the effect that their proper and improper use can have on control limits are individually discussed. Typical control systems supplied by manufacturers of photographic materials are also covered. This includes the care that goes into their preparation and the methods which must be used to get the most out of them. Finally reference is made to some of the simpler statistical methods which a processor can use to determine the variability of his process and set up his own control limits.

A Comparison of the Effect of Residual Sodium and Ammonium Thiosulfates on Image Permanency, *R. W. HENN and NANCY H. KING, Research Laboratories, Eastman Kodak Co., Rochester, N.Y.*

Two documentary copying films were developed, then fixed in (a) sodium, or (b) ammonium thiosulfate fixing baths, and washed to various hypo levels. In some cases salt baths were used to accelerate washing. Incubation of the film showed the fading to be dependent only on the residual thiosulfate ion concentration and to be independent of the cation of the thiosulfate used in the fixing bath. The stability of the films treated in the salt baths proved high, in line with the low residual thiosulfate content.

Processing with Saturated Paper, *SEYMOUR SCHRECK, Specialties, Inc., Syosset, L.I., N.Y.*

In the past, there have been investigations of many techniques for the application of processing solutions to silver halide materials. A simplified approach is the use of a porous web material saturated with the appropriate chemicals. This can eliminate pumps, valves, precision applicators, and other devices. Previous efforts along these lines had resulted in processing and surface defects due to the relative motion between emulsion and web and to the structure of the web. The present development overcomes these disadvantages and gives excellent processing uniformity by means of a new web material and changes in the sandwiching equipment.

Monobath formulations have been developed which are especially suited to this technique, and applicability to a wide variety of recording – processing problems is foreseen. A 16mm magazine processor will be demonstrated.

Thursday Morning, May 12

Photosensitive Systems and Theory

Experimental Studies on the Formation and the Crystallographic Stability of Silver Bromide Grains in Saturated Bromide- and Ammonia-Complex Solutions, *R. MATEJEC, Agfa Research Laboratories, Agfa AG, Leverkusen, West Germany*

Microscopic studies have been made on formation and crystallographic stability of flat silver bromide grains in bromide- and ammonia-complex solutions saturated with respect to silver bromide. While the usual triangular and hexagonal grains are formed at very low crystallization rates, rapid crystallization gives rise to special forms, strongly structurally defective, which frequently show preferred growth directions. The flat grains first produced are not stable in saturated complex solutions in the absence of a protective colloid. The rate of transformation from flat into compact grains (more or less well-defined octahedrons or cubes) increases with temperature and increasing complex concentration; it decreases when protective colloids are added (gelatin, polyvinyl alcohol).

Electrothermography, a New Electrostatic Printing Technique, *P. M. CASSIERS, N.V. Gevaert Photo-Producten, Mortsel, Antwerp, Belgium*

Electrostatic images may be produced by an imagewise dissipation of charge brought about by a rise in temperature rather than by absorption of light. These two mechanisms are compared. For thermal images with good contrast, it is desirable to use a material with a discontinuous resistivity-temperature relation. Many materials, both organic and inorganic, show this relation and typical examples are shown. An attempt is made to correlate this property with others of the same material. Applications for the electrothermographic technique are presented, and such systems are compared with existing copying techniques.

Print-Out Emulsion with Silver Azide as a Component, *YOSHITADA TOMODA, Government Chemical Industrial Research Institute, Tokyo, Hiratsuka-shi, Kanagawa Pref., Japan*

Print-out emulsions have been prepared in which part of the silver bromide has been replaced by silver azide. The effects of small amounts of other additives have been investigated. Formulations are given for print-out emulsions of improved photographic speed. Such emulsions may be used for the detection and the determination of radiation from radioisotopes. It is concluded that the addition of silver azide increases the speed of print-out emulsions, and that these emulsions are useful in estimating high-energy radiations.

Bromine Acceptance by Gelatin, *KINJI OHKUBO, Research Laboratory, Fuji Film Co., Ltd., Minamiashigara, Kanagawa, Japan*

In a model experiment, electrolytically generated nascent bromine was used to simulate the positive holes which diffuse out of a silver bromide crystal, and the consumption of this bromine by various gelatins was measured. Generally, inert gelatins accepted less bromine than did the sensitizing type. An attempt was made to correlate the bromine acceptance of various gelatins with the sensitivities of pure silver bromide emulsions made with them. A correlation was found between the bromine acceptance of gelatin and the print-out density obtained from dried coatings. Experiments were also made to determine which functional groups in the gelatin were bromine acceptors. The bromine consumption of many of the component amino acids as well as a number of synthetic polypeptides was measured, and it was concluded that bromine reacts with only three of the groupings found in gelatin.

Application of the Feigl Iodine-Azide Reaction to Microquantitative Analysis of Sulfur Compounds, *SHIN SUZUKI, Department of Applied Chemistry, Faculty of Engineering, University of Tokyo, Japan*

The Feigl iodine-azide reaction has been applied in the estimation of the adsorption of sulfur compounds on silver bromide. An account of an evaluation of this technique, including experimental details, is given. The dependence of the Feigl reaction on the species of sulfur compound and on the pH of the solution was also investigated. It is concluded that the method is useful in microquantitative analyses of sulfur compounds.

Thursday Afternoon, May 12

Processing Studies

Kinetics of Development by the Ferrous-Ethylenediaminetetraacetate Complex Ion, *T. H. JAMES, Research Laboratories, Eastman Kodak Co., Rochester, N.Y.*

A detailed study was made of the effect of pH, concentration, temperature, neutral salts, silver halide solvents, and quaternary ammonium salts on the rate of development by the Fe-EDTA complex. The rate of development by a dilute solution decreased markedly with increasing pH, but in the presence of a quaternary ammonium salt and sufficient potassium nitrate the rate at high exposure levels varied by less than 2 over the pH range 2.7 – 12.0. Fe-EDTA solutions of higher concentration showed only a small dependence of rate on pH even in the absence of the addenda. Fog formation by the acid solutions was negligible. Increases in pH in the alkaline solutions caused increases in the rates of fog formation and of image development at low exposure levels which correlated with changes in redox potential. The color of the developed silver and its distribution in depth in the emulsion layer varied with the temperature of development and with the gelatin-to-silver ratios of the coatings. Some explanations are suggested.

Kinetic Studies on the Development of Silver Iodide Emulsions, *T. H. JAMES and W. VANSELOW, Research Laboratories, Eastman Kodak Co., Rochester, N.Y.*

The temperature dependence of the rate of development of fine-grain silver iodide emulsions by pyrogallol, catechol, and titanous-EDTA complex developers was determined, and activation energies were calculated for image development and fog formation. The results with a catechol developer were unusual in that the activation energy of the initiation of fog formation was lower than that of image development. Fog formation, however, proceeded by a solution-physical development mechanism, with solution probably the rate-controlling step. Studies of solution-physical development of silver iodide, using a variety of solvents, showed that the net rate depends on the rate of solution under some conditions and largely on the rate of reduction of silver ions under others. Tests made to find an optimum developer for the iodide emulsions gave results which did not correlate with known data on iodobromide emulsions. Best results were obtained with a pyrogallol-sulfite developer of pH 10.

The Influence of Some Addition Agents on the Rate of Development of Liquid Photographic Emulsion, *K. FUTAKI and Y. OHYAMA, Photographic Division, Mitsubishi Paper Mills Co., Ltd., Kyoto, Japan*

The effect on the rate of development of some thiolactam and other addition agents has been examined in a dilute Phenidone

– hydroquinone developer when applied to a silver chloride emulsion in the liquid state. All the addenda have a blue-black toning effect, and the thiolactam compounds have a strong accelerating effect on the rate of development. A systematic variation of the accelerating and of the toning effects was found in the case of compounds of two homologous series in this class. Data is also presented on benzimidazoles and triazaindolizines, which are blue-black toners but which do not have much accelerating effect on development.

The Super-Additivity of Mixtures of Hydroquinone and 3-Aminopyrazoline Derivatives, *H. ULRICH and H. SCHUELER, Agfa Research Laboratories, Agfa AG, Leverkusen, West Germany*

The 1-(*p*-aminophenyl) derivatives of 3-aminopyrazoline show a strong fogging action when used alone, but with hydroquinone they show developing action with pronounced super-additivity. Developer systems containing hydroquinone and these derivatives have been studied and compared with systems containing hydroquinone and 1-phenyl-3-pyrazolidone. It has been found that developers containing the 3-pyrazoline derivatives have a shorter induction period, and lower concentrations of the agents are required for maximum superadditivity. This is explained on the basis of the charges on the ionic species involved.

Measurement of pH Changes in Photographic Coatings during Development, *J. EGGERS, Agfa Research Laboratories, Agfa AG, Leverkusen, West Germany*

Hydrogen ion is liberated during development by organic developing agents. Because of slow diffusion in the emulsion layer, it was thought possible that the pH in the developing emulsion might be much lower than in the bulk solution. Measurements of the pH at the bottom of a developing layer were made on a model consisting of a flat membrane glass electrode coated with a photographic emulsion. Development was initiated by a flash exposure of the coated electrode immersed in the developer. By simultaneous flash exposure of a glass plate similarly coated with emulsion and immersed in the developer, the growth of density parallel to the pH change could be followed. Measurements were made with different silver coatings and in developers of different buffer capacities.

The Color of Colloidal Silver Sols in Gelatin, *E. KLEIN and H. J. METZ, Agfa Research Laboratories, Agfa AG, Leverkusen, West Germany*

The size of the compact silver particles obtained by physical development of silver halide emulsions may be varied between 20 and 250 millimicrons by changing the amount of nuclei in the solution. Coatings developed in this way show a great variety in their reflected and transmitted colors, as has already been observed for silver hydrosols by several authors. These effects may be calculated using the constants of pure silver and the refractive index of the medium, according to the theory of Mie. A qualitative agreement between theory and experiment is obtained, but it is found that the coatings exhibit differences in color according to whether the silver has originated from the bromide or the chloride. It is concluded that contamination of the developed silver is responsible for these differences.

Friday Morning, May 13

Sensitometry, Reciprocity, and the Characteristic Curve

An Equation of State for the Photographic System, *R. W. SWENSON, Photo Products Dept., E. I. du Pont de Nemours & Company, Parlin, N.J.*

This paper considers the addition of a third dimension, Chemical Sensitization, to the H & D curve, the other dimensions being Density and Exposure. The implications of this are explored mathematically and a number of relationships are derived, including one for gamma. This treatment of the photographic system does not depend on the mechanism or the chemical nature of the product of chemical sensitization or latent-image formation. This description of the photographic system is illustrated quantitatively for an experimental emulsion at both low- and high-exposure intensities.

Spread and Contrast Transfer Functions of Photographic Materials, *H. FRIESER, Institut für wissenschaftliche Photographie der Technischen Hochschule München, West Germany*

Some methods for the determination of the functions are described and the possibilities of errors are discussed. The spread and transfer functions of several photographic materials have been measured and the results are compared with the findings of other authors. An attempt has been made to derive the functions theoretically from the optical properties of the layers. These results are compared with experimental findings.

Contribution to the Theory of the Density Curve, *H. FRIESER (now at the Institut für wissenschaftliche Photographie der Technischen Hochschule München, West Germany) and E. KLEIN, Agfa Research Laboratories, Agfa AG, Leverkusen, West Germany*

It has been shown by previous workers that the photographic density curve can be related to four single properties: the distribution of grain size, the "hit or miss" probability of a light quantum, the distribution of grain sensitivity, and the variation of light absorption with coating depth. For coatings with microcystals, which possess a relatively low light sensitivity, the "hit or miss" probability may be ignored. From the present study it appears that for normal photographic coatings with flat gradation, the sensitivity distribution has a negligible effect on the density curve. It only becomes important for very contrasty emulsions. This is related theoretically with the strong dependence of sensitivity on grain size. The distribution of grain sensitivity can be calculated.

Theoretical Considerations Regarding the Relation between the Elementary Density Curve and the Density Curve of Thick Coatings, *E. KLEIN, Agfa Research Laboratories, Agfa AG, Leverkusen, West Germany*

The solution of the integral equation which describes the relation between an elementary density curve and the density curve of a thick coating leads, starting from certain thick coatings, to elementary density curves whose gradient shows several maxima. Correspondingly, the grain size distribution derived from the elementary density curve shows several maxima. It will be shown in what way the mean scatter of the individual grain-size distribution affects the shape of the density curve of the thick coating and how it is related to the dip in the density curve.

Reciprocity Curves for Silver Bromide and Silver Chloride Emulsions, *A. HAUTOT, Physical Laboratory, Université de Liège, Belgium*

A simple approach to reciprocity curves is obtained by using primitive emulsions. This method reveals that different sensitizer types have quite different actions on reciprocity. Some differences and analogies appear when AgBr and AgCl emulsions are compared. In both cases the sulfur content of the emulsion seems to be the main cause of the high-intensity reciprocity failure.

Radiographic and Roentgencinematographic Exposure Techniques in the Millisecond and Microsecond Regions; Measurements and Result, *G. G. GENSINI, Research Dept., St. Joseph's Hospital, Syracuse, N.Y., and S. P. OLECH, Picker X-ray Corp., Syracuse, N.Y.*

The need for fast exposure techniques in medical and industrial radiography has become apparent in recent years. X-ray equipment which operates in the millisecond and microsecond regions is available on an experimental basis, but little is at present known about the behavior of intensifying screens and x-ray films at such short exposure times. Furthermore, timing is normally done at the primary of the x-ray transformer, and this may not necessarily measure the true time of exposure. An instrument in the nature of an x-ray sensitometer has been built. The timing means is a rotating lead disc having a radial slit. This instrument is described and some of the measurements which have been made with it are presented and discussed. Some of the results obtained by radiographic and motion-picture studies made with short and ultrashort exposure techniques are also presented.

Friday Afternoon, May 13

Optics and Image Structure

The Factors Determining Resolution in Photographic Materials, *A. HAUTOT, Physical Laboratory, Université de Liège, Belgium*

A rational classification of the factors determining photographic resolution is proposed. The correlation between resolution and granularity is discussed. Some experimental data are briefly given: the influence of the method of measurement of the resolution on the so-called threshold of resolution; the variation of this threshold with the exposure given to the emulsion; and the similar variation with processing.

On the Relation Between Color Correction and Frequency Response in the Central Part of the Image of a Group of Photographic Systems, *TADEUSZ MALINOWSKI and WALTER MANDLER, Ernst Leitz (Canada) Ltd., Midland, Ontario*

The image quality of a photographic lens is limited, and one of these limitations is due to the secondary spectrum. The optical materials available for consideration have disadvantages which make monochromatic correction difficult. If only "ordinary" glasses are considered, it can then be stated that there is no focal plane possible in which the image for more than two wavelengths is formed. The spectral response of a system (lens and emulsion) can be described by a model curve. The variation in the point spread function of the system with varying color correction of the lens is investigated. The influence of spherical aberration and the chromatic difference in spherical aberration are also treated briefly. It is further shown that a geometrical optical treatment is justified for relative apertures higher than $f/10$.

A Method for Correcting Chromatic Aberrations in Photographic Objectives for Three Wavelengths and Its Application to Cooke Triplets, *WILLIAM BROUWER, Itek Corporation, Boston, Mass.; present address, Diffraction Limited, Inc., East Natick, Mass.*

In attempting to correct triplet objective lenses for more than two wavelengths, a requirement arises for nonexisting glasses. Many such glasses may be realized by replacing single elements by doublets. A method has been developed for selecting glasses for such doublets by the use of three parameters which are functions of the refractive indices of the component glasses at the chosen wavelengths. Extensive use of this method has been made in the design of Cooke triplets. The design procedure is set out and it is shown how the objective may be corrected for three wavelengths.

Mechanical Compensation Zoom Lenses, *ARTHUR COX, Bell & Howell Company, Chicago, Ill.*

In mechanical compensation zoom lenses, the moving components have relative motion among themselves, whereas in optical compensation zoom lenses, the moving components move as a group. The main problems in zoom lens design are: (1) correction of "aperture" aberrations, namely spherical aberration, coma, and astigmatism; (2) correction of distortion; (3) correction of chromatic variation of aberrations; (4) correction of aberrations at finite conjugates; and (5) design for reasonable manufacturing tolerances. These problems and some of the achievements in solving them are described, with specific reference to a 4:1 and a 3:1 zoom lens, both mechanical compensation types.

Mechanical and Optical Evaluation of Amateur Zoom Cameras and Lenses, *FRANK G. BACK, Zoomar Inc., Glen Cove, L.I., N.Y.*

A recent development in amateur photography and cinematography is the replacement of interchangeable lenses and lens turrets by zoom lenses. Neither the professional nor the experienced amateur who is thoroughly familiar with every type of unifocal lens and turret camera knows by what standards to evaluate these new lenses and lens-camera combinations. This paper discusses the features, properties, advantages, and disadvantages of different types of recently developed equipment. Pictures, diagrams, and tables illustrate the points made.

The Design and Development of Optics Associated with Cathode-Ray Tube Memory Storage Systems, *WILLIAM S. FUJIMURA and JOHN D. HAYES, Bausch and Lomb Optical Co., Rochester, N.Y.*

A system is briefly described which consists of optics for two types of channels — information channels, which image the cathode-ray tube raster information bits on a photographic plate; and servo channels, which are used to locate the CRT raster spot. This paper is restricted to the former type of optics, and is principally concerned with the objective lens. Principal requirements are good resolution as measured on an energy distribution basis, and factors permitting the use of a large number of channels in parallel looking at the same CRT face. This led to the choice of a 6-element Altimar-type design. Problems met with in connection with the lens mounts and with special lens testing equipment designed for this project are also described.

Eyepieces in Photography, *GEORGE H. MATTER, Nortronics System Support, Div. of Northrop Corp., Anaheim, Calif.*

The selection of an eyepiece on the basis of magnification required, field of view, and other factors is discussed. After a review of design criteria and design methods, it is suggested that the use of automatic computers should allow a re-evaluation of well-established eyepiece designs with a view to the possible use of aspheric surfaces or rare-earth glasses in order to improve performance. The author concludes with a tabulation of American patents in this field.

This Advance Program has been prepared by the Papers Committee.

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Chemco Photoproducts Company, Incorporated

Chicago Aerial Industries, Incorporated

Consolidated Film Industries

De Jur-Amsco Corporation

E. I. du Pont de Nemours & Company

Eastman Kodak Company

Edgerton, Germeshausen & Grier, Incorporated

The EdnaLite Optical Company, Incorporated

Elgeet Optical Company, Incorporated

Fairchild Camera & Instrument Corporation

Farrand Optical Company, Incorporated

Oscar Fisher Company, Incorporated

The F-R Corporation

General Electric Company

General Film Laboratories Corporation

Graflex, Incorporated

Grant Photo Products, Incorporated

W. & L. E. Gurley Company

Haloid Xerox Incorporated

Hardale Associates

Hi-Speed Equipment, Incorporated

Houston Fearless Corporation

Charles A. Hulcher Company, Incorporated

Philip A. Hunt Company

Hycon Manufacturing Company

Itek Corporation

The Kalart Company, Incorporated

Kollmorgen Optical Corporation

LogEtronics Incorporated

L-W Photo Products Company

J. A. Maurer, Incorporated

The Morse Instrument Company

National Research and Chemical Company

North American Aviation, Incorporated

Pako Corporation

Photogrammetry, Incorporated

Polaroid Corporation

Rolor Industrial Corporation

Simmon Brothers, Incorporated

Technicolor New York Corporation

Tiffen Optical Company

Viewlex, Incorporated

Wollensak Optical Company

Zoomar, Incorporated